THE No.1 MAGAZINE FOR ELECTRONICS TECHNOLOGY & COMPUTER PROJECTS

EVERYDAY

PRACTICAL ELECTRONICS

Vol.33 No.9

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For fighting robots, race cars and boats



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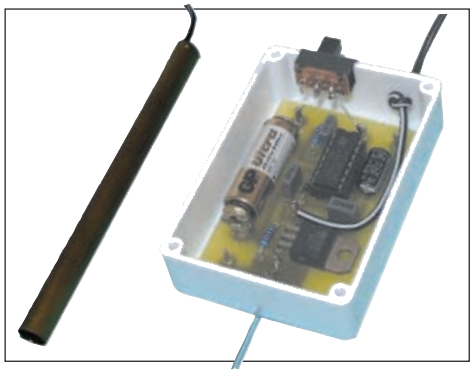
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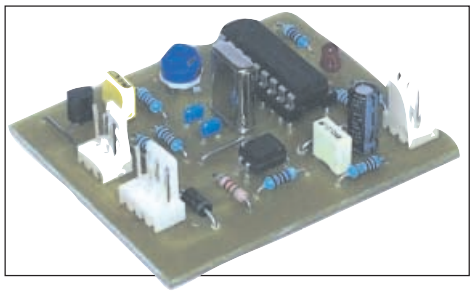
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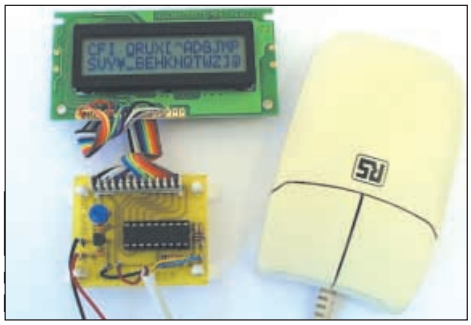
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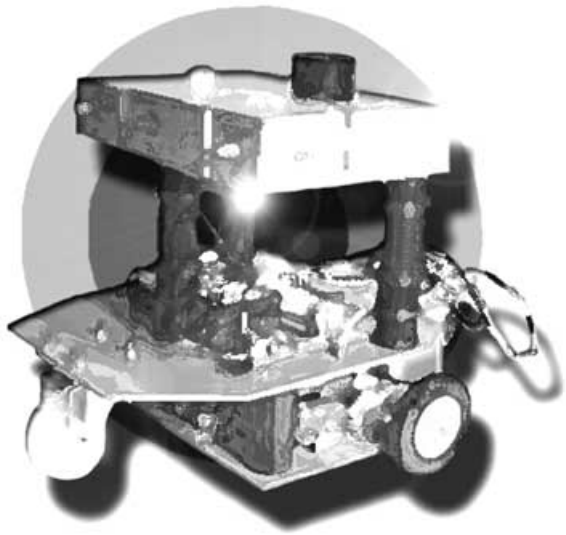
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NEXT MONTH

SMART KARTS – 1

The start of an exciting range of articles describing the construction of a mobile buggy with various sensors and a PIC microcontroller "brain" which can be programmed to tailor the Smart Kart's performance to your requirements. The programming is fully explained so that readers can understand the buggy's "thinking" and modify it as required.
The first article describes the construction of a "line runner" type of buggy, later parts will add to its abilities with extra sensors and actuators attached to the basic chassis.



MOON AND TIDE CLOCK CALENDAR

Presenting a novel design in which the phases of the moon and the ebb and flow of the tide are shown on a graphics liquid crystal display, along with clock and calendar data. It also illustrates how a PS/2 PC keyboard can be interfaced to a PIC-controlled circuit which only infrequently needs to have its settings adjusted, such as this design's real-time factors for the Moon, tide, clock and calendar.
Moon status is displayed graphically, mimicking what you actually see in real life, providing 256 separate progressions from full Moon to full Moon. Tide display is in a form of a bargraph. When the tide is rising, a black triangle expands upwards until its peak reaches the top of the screen. As the tide then falls, the peak of the triangle is slowly flattened, until the tide has fully receded, prior to rising again. Just for fun, there is also an optional little gimmick when high tide occurs – revealed next month!

EPE THEREMIN

Probably one of the wierdest electronic musical instruments ever invented, the Theremin has been around for about 80 years and is probably more popular than ever now. For those not in the know, it is played without any physical contact between the performer and the instrument. The pitch and volume are controlled by separate hands moving near to two "aerials" on the instrument.
This up-to-date design employs no unusual components and is straightforward to build and set up – playing it well may be more of a challenge!

VOLTS CHECKER

When measuring voltages around the home, in the lab, or out in the field, some kind of voltmeter – either a traditional moving coil type, or a digital multimeter – is usually indispensable. However, there are many instances where a basic "go/no go" indication is more than sufficient – for example, when tracing a fault in a car electrical system, or when checking a mains circuit to see whether it is "live".
Housed in a small plastic case, the Volts Checker is a handy, pocket-sized instrument that can be used to check an a.c. or d.c. voltage as low as 3V d.c. or as high as 240V r.m.s. Using the unit could not be easier – just connect the two leads to the circuit under test and an l.e.d. will illuminate if there is a healthy voltage present. Furthermore, there is no need to worry about which node is positive and which is negative, the unit automatically senses any d.c. voltage regardless of polarity. Alternating voltages, such as those produced by step-down transformers in consumer equipment or high-voltage mains domestic circuits, are dealt with just as easily.

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Leads: Parallel (LEAD108) £4.95 / Serial (LEAD76) £4.95 / USB (LEADUAB) £2.95

NEW! USB 'All-Flash' PIC Programmer



USB PIC programmer for all 'Flash' devices. No external power supply making it truly portable. Supplied with box and Windows Software. ZIF Socket and USB Plug A-B lead not incl.
Kit Order Code: 3128KT – **£29.95**
Assembled Order Code: AS3128 – **£39.95**

Enhanced "PICALL" ISP PIC Programmer



Will program virtually ALL 8 to 40 pin PICs plus certain ATMEL AVR, SCENIX SX and EEPROM 24C devices. Also supports In System Programming (ISP) for PIC and ATMEL AVRs. Free software. Blank chip auto detect for super fast bulk programming. Requires a 40-pin wide ZIF socket (not included)
Assembled Order Code: AS3144 – **£54.95**

ATMEL 89xxx Programmer



Uses serial port and any standard terminal comms program. 4 LEDs display the status. ZIF sockets not included. Supply: 16VDC.
Kit Order Code: 3123KT – **£29.95**
Assembled Order Code: AS3123 – **£34.95**

NEW! USB & Serial Port PIC Programmer



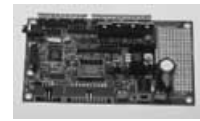
USB/Serial connection. Header cable for ICSP. Free Windows software. See website for PICs supported. ZIF Socket and USB Plug A-B lead extra. 18VDC.
Kit Order Code: 3149KT – **£29.95**
Assembled Order Code: AS3149 – **£44.95**

Introduction to PIC Programming



Go from a complete PIC beginner to burning your first PIC and writing your own code in no time! Includes a 49-page step-by-step Tutorial Manual, Programming Hardware (with LED bench testing section), Win 3.11–XP Programming Software (will Program, Read, Verify & Erase), and a rewritable PIC16F84A that you can use with different code (4 detailed examples provided for you to learn from). Connects to PC parallel port.
Kit Order Code: 3081KT – **£14.95**
Assembled Order Code: AS3081 – **£24.95**

ABC Maxi AVR Development Board



The ABC Maxi board has an open architecture design based on Atmel's AVR AT90S8535 RISC microcontroller and is ideal for developing new designs.
Features:
8Kb of In-System Programmable Flash (1000 write/erase cycles) ● 512 bytes internal SRAM ● 512 bytes EEPROM ● 8 analogue inputs (range 0-5V) ● 4 Opto-isolated Inputs (I/Os are bi-directional with internal pull-up resistors) ● Output buffers can sink 20mA current (direct l.e.d. drive) ● 4 x 12A open drain MOSFET outputs ● RS485 network connector ● 2-16 LCD Connector ● 3·5mm Speaker Phone Jack ● Supply: 9-12VDC.
The ABC Maxi STARTER PACK includes one assembled Maxi Board, parallel and serial cables, and Windows software CD-ROM featuring an Assembler, BASIC compiler and in-system programmer.
Order Code ABCMAXISP – **£79.95**
The ABC Maxi boards only can also be purchased separately at £59.95 each.

Controllers & Loggers

Here are just a few of the controller and data acquisition and control units we have. See website for full details. Suitable PSU for all units: Order Code PSU445 – **£8.95**

Rolling Code 4-Channel UHF Remote



State-of-the-Art. High security. 4 channels. Momentary or latching relay output. Range up to 40m. Up to 15 TXs can be learned by one Rx (kit includes one Tx but more available separately). 4 indicator LEDs.
Rx: PCB 77x85mm, 12VDC/6mA (standby).
Two & Ten Channel versions also available.
Kit Order Code: 3180KIT – **£41.95**
Assembled Order Code: AS3180 – **£49.95**

Computer Temperature Data Logger



Serial port 4-channel temperature logger. °C or °F. Continuously logs up to 4 separate sensors located 200m+ from board. Wide range of free software applications for storing/using data. PCB just 38x38mm. Powered by PC. Includes one DS1820 sensor and four header cables.
Kit Order Code: 3145KT – **£19.95**
Assembled Order Code: AS3145 – **£26.95**
Additional DS1820 Sensors – **£3.95 each**

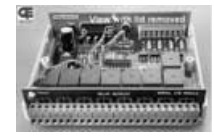
Most items are available in kit form (KT suffix) or pre-assembled and ready for use (AS prefix).

NEW! DTMF Telephone Relay Switcher



Call your phone number using a DTMF phone from anywhere in the world and remotely turn on/off any of the 4 relays as desired. User settable Security Password, Anti-Tamper, Rings to Answer, Auto Hang-up and Lockout. Includes plastic case. 130 x 110 x 30mm. Power: 12VDC.
Kit Order Code: 3140KT – **£39.95**
Assembled Order Code: AS3140 – **£49.95**

Serial Port Isolated I/O Module



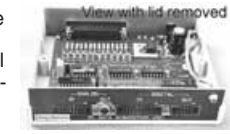
Computer controlled 8-channel relay board. 5A mains rated relay outputs and 4 opto-isolated digital inputs (for monitoring switch states, etc). Useful in a variety of control and sensing applications. Programmed via serial port (use our new Windows interface, terminal emulator or batch files). Serial cable can be up to 35m long. Includes plastic case 130 x 100 x 30mm. Power: 12VDC/500mA.
Kit Order Code: 3108KT – **£54.95**
Assembled Order Code: AS3108 – **£64.95**

Infra-red RC 12-Channel Relay Board



Control 12 on-board relays with included infra-red remote control unit. Toggle or momentary. 15m+ range. 112 x 122mm. Supply: 12VDC/0·5A.
Kit Order Code: 3142KT – **£41.95**
Assembled Order Code: AS3142 – **£51.95**

PC Data Acquisition & Control Unit



Monitor and log a mixture of analogue and digital inputs and control external devices via the analogue and digital outputs. Monitor pressure, temperature, light intensity, weight, switch state, movement, relays, etc. with the apropriate sensors (not supplied). Data can be processed, stored and the results used to control devices such as motors, sirens, relays, servo motors (up to 11) and two stepper motors.

Features
- 11 Analogue Inputs – 0·5V, 10 bit (5mV/step)
- 16 Digital Inputs – 20V max. Protection 1K in series, 5·1V Zener
- 1 Analogue Output – 0-2·5V or 0-10V. 8 bit (20mV/step)
- 8 Digital Outputs – Open collector, 500mA, 33V max
- Custom box (140 x 110 x 35mm) with printed front & rear panels
- Windows software utilities (3·1 to XP) and programming examples
- Supply: 12V DC (Order Code PSU203)

Kit Order Code: 3093KT – **£69.95**
Assembled Order Code: AS3093 – **£99.95**

Hot New Kits This Summer!

Here are a few of the most recent kits added to our range. See website or join our email Newsletter for all the latest news.

NEW! EPE Ultrasonic Wind Speed Meter



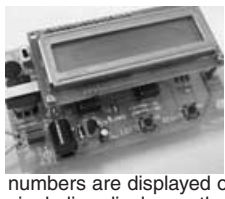
Solid-state design wind speed meter (anemometer) that uses ultrasonic techniques and has no moving parts and does not need calibrating. It is intended for sports-type activities, such as track events, sailing, hang-gliding, kites and model aircraft flying, to name but a few. It can even be used to monitor conditions in your garden. The probe is pointed in the direction from which the wind is blowing and the speed is displayed on an LCD display.

Specifications

- Units of display: metres per second, feet per second, kilometres per hour and miles per hour
- Resolution: Nearest tenth of a metre
- Range: Zero to 50mph approx.

Based on the project published in Everyday Practical Electronics, Jan 2003. We have made a few minor design changes (see web site for full details). Power: 9VDC (PP3 battery or Order Code PSU345).
Main PCB: 50 x 83mm.
Kit Order Code: 3168KT – **£34.95**

NEW! Audio DTMF Decoder and Display



Detects DTMF tones via an on-board electret microphone or direct from the phone lines through the onboard audio transformer. The numbers are displayed on a 16-character, single line display as they are received. Up to 32 numbers can be displayed by scrolling the display left and right. There is also a serial output for sending the detected tones to a PC via the serial port. The unit will not detect numbers dialled using pulse dialling. Circuit is microcontroller based.
Supply: 9-12V DC (Order Code PSU345).
Main PCB: 55 x 95mm.
Kit Order Code: 3153KT – **£17.95**
Assembled Order Code: AS3153 – **£29.95**

NEW! EPE PIC Controlled LED Flasher



This versatile PIC-based LED or filament bulb flasher can be used to flash from 1 to 160 LEDs. The user arranges the LEDs in any pattern they wish. The kit comes with 8 superbright red LEDs and 8 green LEDs. Based on the Versatile PIC Flasher by Steve Challinor, *EPE* Magazine Dec '02. See website for full details. Board Supply: 9-12V DC. LED supply: 9-45V DC (depending on number of LED used). PCB: 43 x 54mm.
Kit Order Code: 3169KT – **£10.95**

Most items are available in kit form (KT suffix) or assembled and ready for use (AS prefix)

FM Bugs & Transmitters

Our extensive range goes from discreet surveillance bugs to powerful FM broadcast transmitters. Here are a few examples. All can be received on a standard FM radio and have adjustable transmitting frequency.

***MMTX'* Micro-Miniature 9V FM Room Bug**



Our best selling bug! Good performance. Just 25 x 15mm. Sold to detective agencies worldwide. Small enough to hide just about anywhere. Operates at the 'less busy' top end of the commercial FM waveband and also up into the more private Air band.
Range: 500m. Supply: PP3 battery.
Kit Order Code: 3051KT – **£8.95**
Assembled Order Code: AS3051 – **£14.95**

***HPTX'* High Power FM Room Bug**



Our most powerful room bug. Very Impressive performance. Clear and stable output signal thanks to the extra circuitry employed.
Range: 1000m @ 9V. Supply: 6-12V DC (9V PP3 battery clip suppied). 70 x 15mm.
Kit Order Code: 3032KT – **£9.95**
Assembled Order Code: AS3032 – **£17.95**

***MTTX'* Miniature Telephone Transmitter**



Attach anywhere along phone line. Tune a radio into the signal and hear exactly what both parties are saying. Transmits only when phone is used. Clear, stable signal. Powered from phone line so completely maintenance free once installed. Requires no aerial wire – uses phone line as antenna. Suitable for any phone system worldwide. Range: 300m. 20 x 45mm.
Kit Order Code: 3016KT – **£7.95**
Assembled Order Code: AS3016 – **£13.95**

3 Watt FM Transmitter



Small, powerful FM transmitter. Audio preamp stage and three RF stages deliver 3 watts of RF power. Can be used with the electret microphone supplied or any line level audio source (e.g. CD or tape OUT, mixer, sound card, etc). Aerial can be an open dipole or Ground Plane. Ideal project for the novice wishing to get started in the fascinating world of FM broadcasting. 45 x 145mm.
Kit Order Code: 1028KT – **£22.95**
Assembled Order Code: AS1028 – **£34.95**

25 Watt FM Transmitter

Four transistor based stages with a Philips BLY89 (or equivalent) in the final stage. Delivers a mighty 25 Watts of RF power. Accepts any line level audio source (input sensitivity is adjustable). Antenna can be an open dipole, ground plane, 5/8, J, or YAGI configuration. Supply 12-14V DC, 5A. Supplied fully assembled and aligned – just connect the aerial, power and audio input. 70 x 220mm.
Order Code: 1031M – **£124.95**

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Order Code EPL500 – **£149.95**
30, 130, 200 and 300-in-1 project labs also available – see website for details.

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With over 300 projects in our range we are the UK's number 1 electronic kit specialist. Here are a few other kits from our range.

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3087KT – 1W Stereo Amplifier £4.95
3105KT – 18W BTL mono Amplifier £9.95
3106KT – 50W Mono Hi-fi Amplifier £19.95
3143KT – 10W Stereo Amplifier £9.95
1011-12KT – Motorbike Alarm £12.95
1019KT – Car Alarm System £11.95
1048KT – Electronic Thermostat £9.95
1080KT – Liquid Level Sensor £6.95
3003KT – LED Dice with Box £7.95
3006KT – LED Roulette Wheel £8.95
3074KT – 8-Ch PC Relay Board £29.95
3082KT – 2-Ch UHF Relay £26.95
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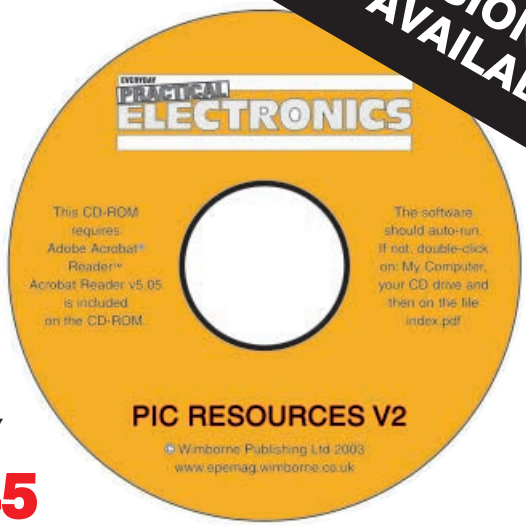
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- PIC Toolkit Mk3 (TK3 hardware construction details), John Becker, Oct '01
- PIC Toolkit TK3 for Windows (software details), John Becker, Nov '01

Plus these useful texts to help you get the most out of your PIC programming:

- How to Use Intelligent L.C.D.s, Julyan Ilett, Feb/Mar '97
- PIC16F87x Microcontrollers (Review), John Becker, April '99
- PIC16F87x Mini Tutorial, John Becker, Oct '99
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- Using TK3 with Windows XP and 2000, Mark Jones, Oct '02
- PIC Macros and Computed GOTOs, Malcolm Wiles, Jan '03
- Asynchronous Serial Communications (RS-232), John Waller, unpublished
- Using I^2C Facilities in the PIC16F877, John Waller, unpublished
- Using Serial EEPROMs, Gary Moulton, unpublished
- Additional text for EPE PIC Tutorial V2, John Becker, unpublished

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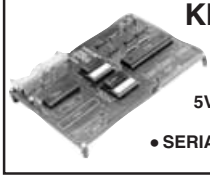


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- **HIGH POWER**
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★ TENS UNIT ★

DUAL OUTPUT TENS UNIT

As featured in March '97 issue.

Set of 4 spare electrodes **£6.50**

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KIT 866. . Full kit including four electrodes £32.90

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Full set of top quality *NEW* components for this educational series. All parts as specified by *EPE*. Kit includes breadboard, wire, croc clips, pins and all components for experiments, as listed in introduction to Part 1.
**Batteries and tools not included.*

TEACH-IN 2000 -

KIT 879 £44.95
MULTIMETER £14.45

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An innovative and exciting project. Wave the wand through the air and your message appears. Programmable to hold any message up to 16 digits long. Comes pre-loaded with "MERRY XMAS". Kit includes PCB, all components & tube plus instructions for message loading.

KIT 849£16.99

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20kHz-140kHz
NEW DESIGN WITH 40kHz MIC.



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Based on our Mk1 design and preserving all the features, but now with switching pre-regulator for much higher efficiency. Panel meters indicate Volts and Amps. Fully variable down to zero. Toroidal mains transformer. Kit includes punched and printed case and all parts. As featured in April 1994 *EPE*. An essential piece of equipment.



Kit No. 845£64.95

ULTRASONIC PEsT SCARER

Keep pets/pests away from newly sown areas, fruit, vegetable and flower beds, children's play areas, patios etc. This project produces intense pulses of ultrasound which deter visiting animals.



- KIT INCLUDES ALL COMPONENTS, PCB & CASE
- EFFICIENT 100V TRANSDUCER OUTPUT
- COMPLETELY INAUDIBLE TO HUMANS
- UP TO 4 METRES RANGE
- LOW CURRENT DRAIN

KIT 812. £15.00

SIMPLE PIC PROGRAMMER

KIT 857... £12.99

Includes PIC16F84 chip disk, lead, plug, p.c.b., all components and instructions

Extra 16F84 chips £3.84
Power Supply £3.99

MAGENTA BRAINIBOT I & II

NEW

- Full kit with ALL hardware and electronics
- As featured in *EPE* Feb '03 – KIT 910
- Seeks light, beeps, avoids obstacles
- Spins and reverses when 'cornered'
- Uses 8-pin PIC
- ALSO KIT 911 – As 910 *PLUS* programmable from PC serial port – leads and software CD provided



KIT 910 £16.99 **KIT 911 £24.99**

PIC 16F84 MAINS POWER 4-CHANNEL CONTROLLER & LIGHT CHASER

- ZERO VOLT SWITCHING
- OPTO ISOLATED 5 Amp
- 12 KEYPAD CONTROL
- HARD-FIRED TRIACS
- WITH SOURCE CODE
- SPEED & DIMMING POT.
- EASILY PROGRAMMED

Kit 855 £39.95

PIC 16F84 LCD DISPLAY DRIVER

INCLUDES 1-PIC16F84 WITH DEMO PROGRAM SOFTWARE DISK, PCB, INSTRUCTIONS AND 16-CHARACTER 2-LINE **LCD DISPLAY**

Kit 860 £19.99

Power Supply £3.99

FULL PROGRAM SOURCE CODE SUPPLIED – DEVELOP YOUR OWN APPLICATION!

Another super PIC project from Magenta. Supplied with PCB, industry standard 2-LINE × 16-character display, data, all components, and software to include in your own programs. Ideal development base for meters, terminals, calculators, counters, timers – Just waiting for your application!

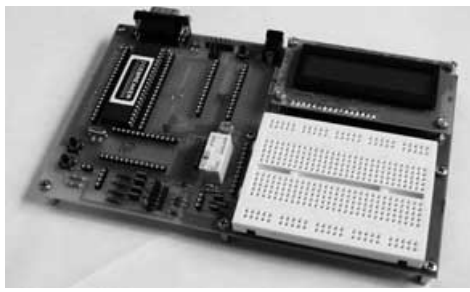
8-CHANNEL DATA LOGGER

NEW!

As featured in Aug./Sept. '99 *EPE*. Full kit with Magenta redesigned PCB – LCD fits directly on board. Use as Data Logger *or* as a test bed for many other 16F877 projects. Kit includes programmed chip, 8 EEPROMs, PCB, case and all components.

KIT 877 £49.95 inc. 8 × 256K EEPROMS

ICEBREAKER



PIC Real Time In-Circuit Emulator

- Icebreaker uses PIC16F877 in circuit debugger
- Links to Standard PC **Serial** Port (lead supplied)
- Windows™ (95+) Software included
- Works with MPASM and MPLAB Microchip software
- 16 x 2 L.C.D., Breadboard, Relay, I/O devices and patch leads supplied

As featured in March '00 *EPE*. Ideal for beginners AND advanced users.
Programs can be written, assembled, downloaded into the microcontroller and run at full speed (up to 20MHz), or one step at a time.
Full emulation means that all I/O ports respond exactly and immediately, reading and driving external hardware.
Features include: Reset; Halt on external pulse; Set Breakpoint; Examine and Change registers, EEPROM and program memory; Load program, Single Step with display of Status, W register, Program counter, and user selected 'Watch Window' registers.

KIT 900 . . . £34.99

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EPE TEACH-IN 2004

THE LATEST SERIES – STARTED NOV '03
ALL PARTS INCLUDING PROTOTYPE BREADBOARD AND WIRE – AS LISTED ON p752 NOV. ISSUE (EXCL MISC.)
"A BRILLIANT NEW ELECTRONICS COURSE"

KIT 920 . . . £29.99

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EPE PIC Tutorial V2

EPE APR/MAY/JUNE '03 and PIC RESOURCES CD

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PIC TUTOR 1

MARCH - APRIL - MAY '98 EPE SERIES 16F84

PIC TUTOR BOARD KIT

Includes: PIC16F84 Chip, TOP Quality PCB printed with Component Layout and all components* (*not ZIF Socket or Displays). Included with the Magenta Kit is a disk with Test and Demonstration routines.

KIT 870 £27.95, Built & Tested £42.95

Optional: **Power Supply – £3.99, ZIF Socket – £9.99**
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Kit 862 £29.99

Power Supply £3.99

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Kit 863 £18.99

FULL SOURCE CODE SUPPLIED
ALSO USE FOR DRIVING OTHER POWER DEVICES e.g. SOLENOIDS

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MAGENTA

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Not Again!

We are about to go to press with this issue and Peter (our typesetter and advertisement copy controller) has just pointed out that we still need the *News* pages – John has that under control – and my *Editorial*, which I had forgotten about! It seems that the months go by at an ever faster rate, but I guess that comes with age. Once again lacking some inspiration I thought I would look at what other Editors of electronics magazines from around the world write about in their editorials.

Oz and US

In Australia it seems there is concern that compact fluorescent lamps do not live up to the promise of lasting five to eight times longer than normal light bulbs. (We notice some in the UK claim 10 times longer life.) Whilst in the USA they are much more interested in telling all their advertisers what their features will be in 2005.

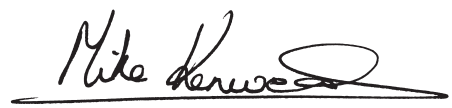
I guess that reflects a concern for the environment and one for marketing, which just possibly also reflects the political outlook in those countries.

International

Of course, *EPE* is truly international and I guess you could say that our editorials tend to concentrate on issues of direct concern to electronics enthusiasts – last month it was the problems with getting copies of *EPE*; in July intermittent faults and software bugs; in June the low price of electronics gadgets and innovative projects we have published; May concentrated on the Amateur Scientist CD-ROM we sell – see the *Direct Book Service* pages, whilst April was a review of what goes on in the editorial office.

When I look back at this lot it is pretty mundane stuff, but hopefully it's what is of interest and concern to you, our readers. Some of it is also aimed at keeping you interested and informed on all things *EPE* and hopefully you will keep reading. I guess you can say that we are truly a magazine for electronics enthusiasts everywhere, whether they are professionals, students, retired technicians or engineers, or pure hobbyists.

Hopefully you will find plenty to interest you within these pages.



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Constructional Project

Rainbow Lighting Controller



David Geary

Brighten up your garden's night-time colour scheme!

THIS design originated both from the annoyance of frequently changing conventional small lamps in a garden lighting set, the addition of a small water feature and the subsequent desire to "do something different". Using the latest developments in l.e.d. technology seemed the obvious answer.

Replacing lamps with l.e.d.s brings optical problems. Inevitably, decorative lighting is required to emit light in all directions, and this would either require a cluster of l.e.d.s, or a reflector, mirror, diffuser arrangement.

Thoughts along these lines then provoked the question "what colour?", and so the perhaps less obvious answer of "all colours". Since all colours can be derived from a mix of red, blue, and green, it should be possible to add life to a static display by varying the colour of emitted light. In practice, mixing colours to get a single, varying colour light is near impossible without specialist optics. However, the display remains interesting and different with various mixes of colours being visible.

All of this leaves the original problem of optics. The project described here gets around this by using a reversing light housing available from Halfords – complete with mirror and diffusing lens.

The controller described here is simple, and can be easily adapted for small incandescent lamps, or a chain of l.e.d.s – indeed, there is no reason why one controller could not be adapted by adding some buffer gates and extra transistor stages to run a large number of displays.

After watching the prototype for a while, this is the electronic equivalent of the Lava Lamp!

Choice of L.E.D.

The design started with some research into the l.e.d.s available. An RGB (red, green, blue) l.e.d. is available, but the brightness of the various colours varies. The cost of these l.e.d.s is significant and a number would be required.

However, it is possible to purchase very high brightness l.e.d.s individually. Farnell (see *Shoptalk* page) offer a range of l.e.d.s designed for external signage at reasonable cost.



The design was intended to run from the 12V a.c. supply provided with the existing lighting set, and therefore running the l.e.d.s at or near their maximum current rating was not a design constraint.

For all practical purposes, l.e.d.s are generally considered to have an infinite life. It is important to recognise, though, that while they may remain working, light output reduces over time. This project therefore does not have an infinite life, and l.e.d.s may need replacing every few years to maintain the effectiveness of the display.

Some time was spent selecting the correct l.e.d.s to use; the green and blue colours are very effective. The red l.e.d. was originally a "Giant Red", which provides a deep red colour. However, it is impossible to focus this into the back of the reflector, and it was felt to lack "punch". This was then changed to those specified later, which are a lighter red, very bright, but need careful focussing into the reflector.

Other Parameters

The project needs to be installed in the garden, therefore it needs to be waterproof and be able to survive cold winters. As said, the author's available supply is 12V a.c., with a few hundred milliamps easily available.

Having decided to use red, green, and blue as the l.e.d. colours, the design should fade rather than switch between them. A variety of modes should enable testing as well as an appropriate display once installed.

Additionally, it would be desirable to make the final design self-contained and cheap enough to be repeatable around the garden.

Ripe for PICing

The final circuit for the Rainbow Lighting Controller is fairly simple, as shown in Fig.1.

It uses a PIC16F84 microcontroller, IC1, whose pins RA0 to RA2 control three power transistors, TR1 to TR3, via buffering resistors R1 to R3. The transistors then control l.e.d.s D1 to D5, which are buffered by resistors R4 to R6.

In the prototype the PIC is operated at 3·579545MHz, as set by crystal X1 in

conjunction with capacitors C1 and C2. This frequency is not critical and other crystal speeds may be used, such as the more common 3·2768MHz or 4MHz devices.

The power supply can be provided by any unit intended for outdoor use and capable of supplying 12V a.c. at a minimum of about 100mA. The author's unit was powered by the supply from an existing commercial lighting set.

The 12V a.c. supply is rectified by REC1, smoothed by capacitor C6 and regulated down to +12V d.c. by IC3. This supply is used to power the l.e.d.s. It is also regulated down to +5V by IC2, which then supplies power to the PIC. Capacitors C3 and C4 provide local smoothing.

Power may alternatively be provided by a 12V car battery, in which case bridge rectifier REC1 and 12V regulator IC3 may be omitted.

When power is first applied to the circuit, the PIC is reset via its $\overline{\text{MCLR}}$ pin, with resistor R7 and capacitor C5 providing a brief delay in the response.

An 8-way dual-in-line (d.i.l.) switch module, controls the modes available via its switches, S1 to S8. They are connected to Port B pins RB0 to RB7, which are biassed normally-low via 8-way resistor s.i.l. (single-in-line) module RM1.

Switch Modes

The switch mode functions are outlined in Table 1.

The brightness of the l.e.d.s is controlled using pulse width modulation (PWM). The maximum brightness is, of course, controlled by the series resistors R4 to R6.

Table 1: Switch (S1 to S8) Mode Functions

Switch	*PIC Pin*	*Purpose*	*Option*
S1	RB0	Fade/Overlap	off for fade
S2	RB1	Run/Freeze	off to freeze at that point in the cycle
S3	RB2	Red High Start	off for high brightness on reset and static display
S4	RB3	Blue High Start	off for high brightness on reset and static display
S5	RB4	Green High Start	off for high brightness on reset and static display
S6 to S8	RB5 to RB7	Speed	set in binary, 000 for fastest, 111 for slowest, RB5 = LSB, RB7 = MSB

The blue and green l.e.d.s specified are both static sensitive and easily destroyed by over-current. Whilst the design is clearly ripe for customisation, be very careful to ensure appropriate resistors are calculated. Table 2 shows the data for the specified l.e.d.s and the web address for the datasheet. Note the figure for V_{fwd} for the blue and red l.e.d. is doubled as two are used in series.

Construction

The Rainbow Lighting Controller is constructed on stripboard, whose assembly and track cutting details are shown in Fig.2.

Take care to make all track breaks first. A proper spot face cutter is a worthwhile investment! Assemble the components in order of ascending size, but starting with the d.i.l. (dual-in-line) socket and the on-board link wires.

The prototype originally showed just how susceptible to stray capacitance a PIC running fairly fast can be, indeed different settings of the d.i.l. switches affected the reliable starting of the clock. It was found to be important that redundant lengths of track around the crystal side of the PIC (and the double-breaks shown) should be removed.

Table 2: L.E.D. Data

L.E.D.	*Farnell*	*V_{fwd}*	*mA max*	*V max.*	*R value*	*R diss*
Blue	366-4569	7·4	25	12	184Ω	115mW
Green	302-7752	4·0	24	12	333Ω	192mW
Red	623-672	4·2	20	12	390Ω	156mW

Data: www.farnell.com/datasheets/24360.pdf, /41355.pdf, /5727.pdf, respectively

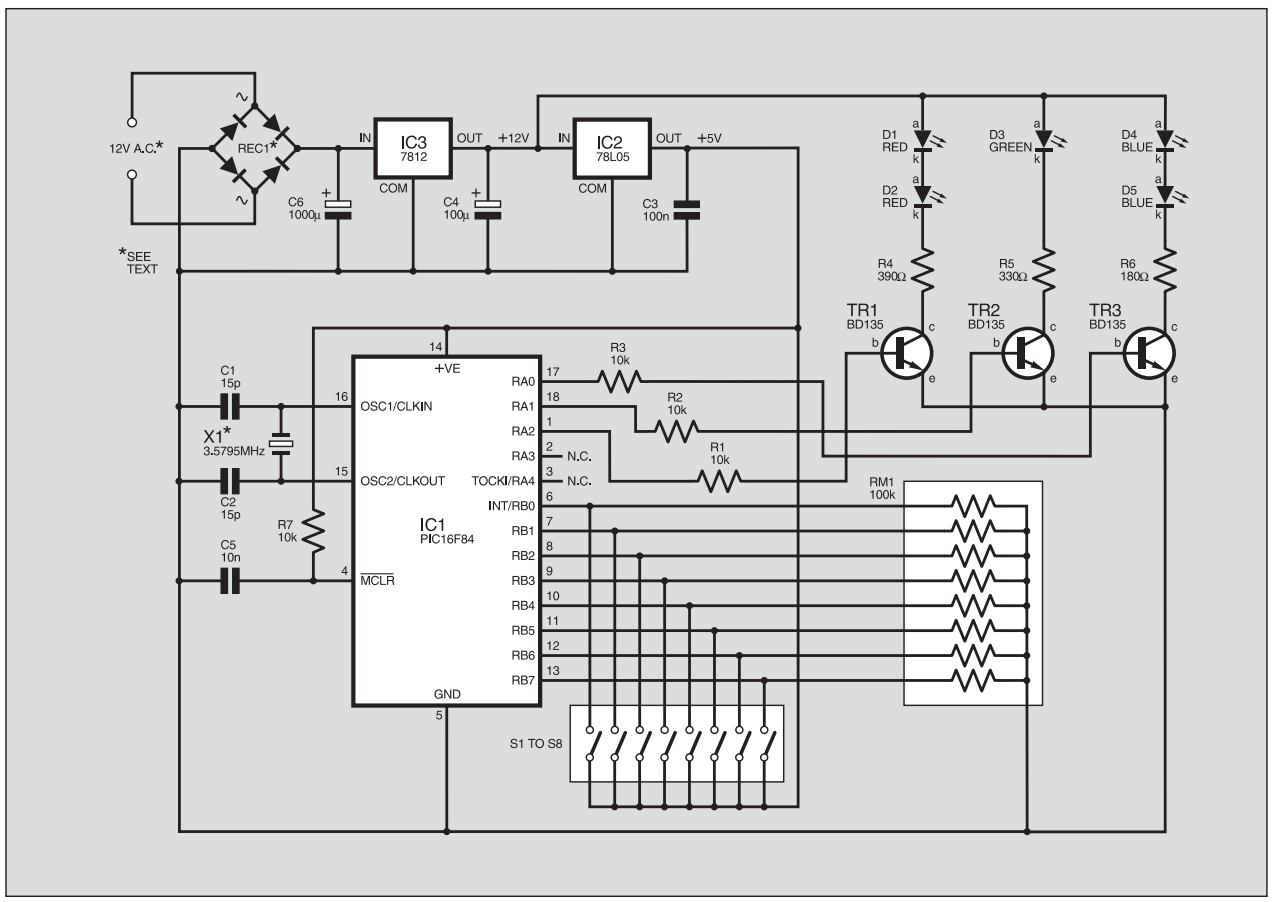
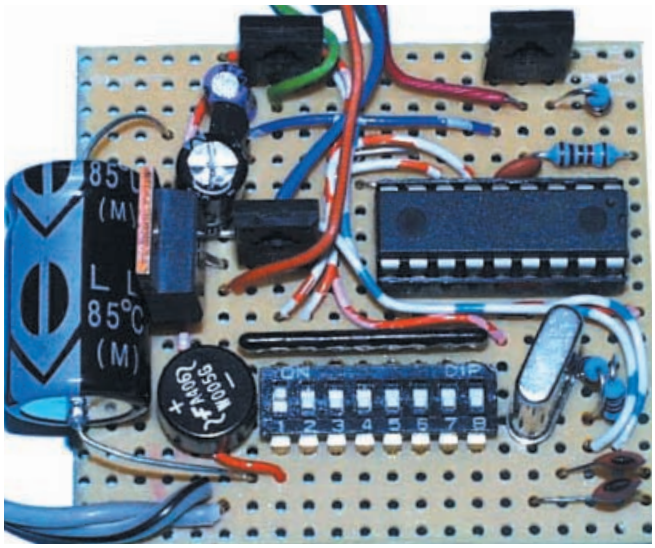
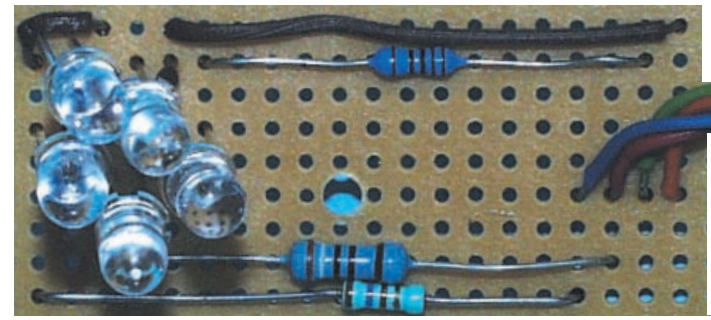


Fig.1. Complete circuit diagram for the Rainbow Lighting Controller.





(Above) The "rainbow" display l.e.d.s mounted on an optional piece of stripboard together with their ballast resistors. This board is mounted inside the lamp reflecting dome.

(Left) The author's prototype circuit board component layout. In the final version, and layout diagram, some of the wire links have been repositioned, a larger piece of stripboard has been used, and capacitor C6 is in a different place.

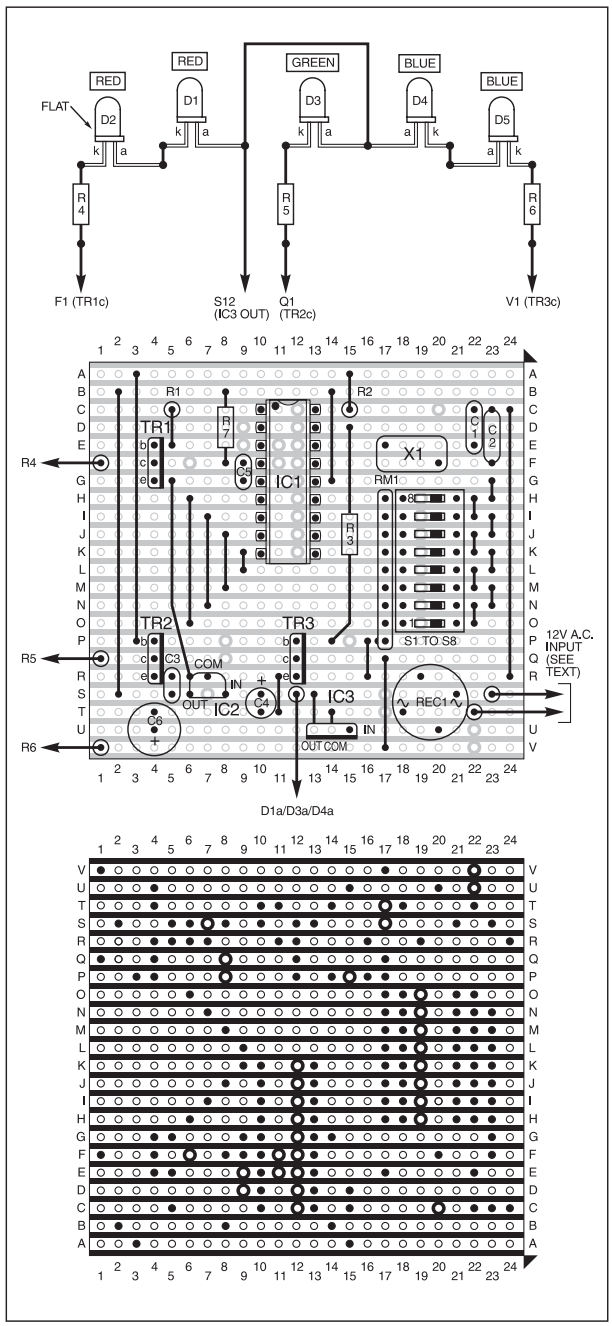


Fig.2. Circuit board component layout, wiring details and details of breaks required in the copper tracks.

The non-PIC side pins of the d.i.l. switch are shown as linked together on the diagram – using small individual track-bridging links. Note the dot on one end of resistor module RM1 and make sure this is positioned on the stripboard as shown.

Lighting Enclosure

The control circuit stripboard is mounted in a small box bolted to the rear of the chosen lighting head, with wires passing through holes suitably drilled in both.

The design of the lighting head is one ripe for experimentation. The lighting enclosure used by the author was a Halfords Ring

COMPONENTS

Resistors

R1 to R3, R7	10k (4 off)
R4	390Ω
R5	330Ω
R6	180Ω (3 off)
RM1	100k s.i.l. 8-way commoned resistor module

All 0·25W 5% or better.

See SHOP TALK page

Capacitors

C1, C2	15p disc ceramic, 2·5mm pitch (2 off)
C3	100n disc ceramic, 2·5mm pitch
C4	100μ radial elect. 25V
C5	10n disc ceramic, 2·5mm pitch
C6	1000μ radial elect. 35V

Semiconductors

D1, D2	red l.e.d., 5mm, high-brightness (2 off)	(see text)
D3	green l.e.d., 5mm, high-brightness	
D4, D5	blue l.e.d., 5mm, high brightness (2 off)	
TR1 to TR3	BD135 medium power *npn* transistor (3 off)	
IC1	PIC16F84A microcontroller, pre-programmed (see text)	
IC2	78L05 +5V 100mA voltage regulator	
IC3	7812 +12V 1A voltage regulator (see text)	
REC1	W005 50V 1A bridge rectifier (see text)	

Miscellaneous

S1 to S8	s.p.s.t. d.i.l. 8-way switch module
X1	crystal 3·5795MHz (see text)

Stripboard, 24 holes 22 strips; 18-pin d.i.l. socket; lighting enclosure to suit application (see text); power supply (see text); small plastic case for stripboard (see text); connecting wire; solder, etc.

Approx. Cost Guidance Only

£16 *excl. lamp*

RL015 fitting. Other housing types may be used and modified appropriately. The Halfords type was modified by removing the bracket that normally serves as a lampholder and trimming it to a simple bracket.

This can be used to mount the l.e.d.s and resistors R4 to R6 on a separate piece of stripboard if preferred. Leave a one-centimetre l.e.d. lead length so they can be angled by gently bending the leads. This approach would offer the flexibility to experiment with the l.e.d. lighting head without disturbing the rest of the circuitry.

Power is fed through the hole in the fitting provided for the purpose and back through the rear of the fitting to a "chocolate block" (or similar method), from which loose wires connect to the board.



The bulbholder bracket removed from the lamp housing.

Installation

You will need to experiment with the installation site for the best results. Given the optics of the fitting described, make sure that the l.e.d.s point towards the centre of the back of the fitting to maximise efficiency.

Note that the red l.e.d.s specified have a very narrow viewing angle. In the prototype, one l.e.d. was positioned to face diagonally across the fitting to ensure the maximum "bounce" around inside the fitting, while the other faced the centre of the back of the fitting as described above.

Remember that the specified types are static sensitive, so until they are installed make sure you use a wrist strap, or otherwise ensure that you discharge static electricity from your body before handling them. They are also very prone to failure from over-current so be careful to ensure the current limiting resistors R4, R5, and R6 are correctly connected.

Make sure that the unit is properly waterproofed, regardless of the "lip" on the inside of most small enclosures. At one stage with the prototype it stopped working, and the author was greeted by a water-filled box on investigation!

Some PVC tape around the lid, and between the fitting and enclosure, solved the problem. Some mastic between the back of the fitting and the enclosure might help with persistent leaks – or, of course, a fitting big enough to enclose the electronics as well!

Software

The PIC software was developed and programmed in the TASM dialect using *EPE Toolkit TK3*. The latter may also be used for translating from TASM to MPASM to suit other programming assemblers if required. The hex file is in the standard MPASM format and does not need translating.

For those who are interested in PIC programming – PIC Port A is used for output only, and Port B is used purely for reading the d.i.l. switch. The principle is that initial brightness values (software variables **red, blue, and green**) are set by the d.i.l. switch. The values are swept between 1 and 255 under the control of a fade-mode variable (**fctrl**). This controls which colour is varied at each sweep through the program.

Varying the value in **fctrl** therefore varies the behaviour of the controller. To achieve non-overlap mode, where only one colour is visible at a time, this is set at "00000001" and rotated left at each set of 256 sweeps through the first part of the program. For colour overlap, this is left at its default value of 00001001.

It is possible to prevent any colour change by selecting static mode (Port B,1 high) – this option allows the display to be frozen at any time (see **stat** routine).

The overall speed control is effected at the beginning of the code headed **start**, by simply calling the display routine (**DIS**) repetitively. This routine effects Pulse Width Modulation control of each l.e.d. by copying the brightness level to a temporary variable, and then decrementing until the variable for each colour reaches zero, at which point the relevant l.e.d. is switched off.

In use, each l.e.d. is slightly lit at nearly all times. This does not detract from the overall effect and is useful for checking all is well!

Resources

Software, including source code files, for the Rainbow Lighting Controller is available on 3·5inch disk from the Editorial office (a small handling charge applies – see the *EPE PCB Service* page). It can also be downloaded *free* from the *EPE* Downloads page, accessible via the home page at **www.epemag.wimborne.co.uk**. It is held in the PICs folder, under Rainbow Lighting. Download all the files within that folder.

This month's *Shop Talk* provides information about obtaining pre-programmed PICs, and the sourcing of components. □



The display l.e.d.s mounted inside the lamp housing. Note the l.e.d.s face inwards towards the centre of the light reflector.



Completed controller unit mounted on the rear of the lighting head.

TECHNO-TALK ANDY EMMERSON

From Pots To Pans

The telephone technology used since the 1870s has finally reached its use-by date, as Andy Emmerson reports.

IF LOVE means never having to say you're sorry, then techno-talk means not having to apologise for talking technical. And that's what we're doing this month but hopefully in an understandable way.

Does it really matter how telephones work, as long as they do work? Probably not for most people, but we're different, aren't we? We enjoy taking telephones to bits and seeing if we can recognise any of the parts inside. We probably even fancy we know how the network functions, at least at outline level.

Not for much longer, however. The telephone system – or at least the majority of the UK network – is changing forever, hotly followed by many other systems around the world. British Telecom is the first in the world to commit its entire network to the new technology but that distinction need not concern us much.

Old POTS, New PANS

Twenty years ago some bright spark coined the phrase POTS and PANS, at a time when stored processor control (i.e. computer-controlled) telephone exchanges were a major novelty. The Plain Old Telephone System (POTS for short) was being enhanced with Positively Amazing New Services (PANS) and we all gasped with admiration. Soon afterwards came the transition from analogue to digital, which brought clearer calls and much improved reliability.

What none of these enhancements did was alter the nature of the telephone network, which relied on switched circuits connecting subscribers. In other words, from my telephone to yours was a static wired (or part-wire, part radio) connection, passing through one or more telephone exchanges on the way. For the entire duration of our call you and I would have the exclusive use of this connection, a concept that had not altered since the first experiments of Graham Bell and others in the 1870s.

A century and a quarter without fundamental change is not bad going in the modern era but it is coming rapidly to an end. What's more, the new technology is truly amazing, even though its announcement was lost in the fog of words that is all too common in the information overload that we tend to suffer now.

Cloud Cover

If you read books on networking you'll know that clouds are a handy way of portraying complex networks in diagrams. The fog can easily obscure vital information, however, as was the case recently when BT took the wraps off its 21st Century Network (21CN). Most coverage majored on the £1 billion annual cost savings expected, overshadowing the more fundamental implications of what is truly a radical change in direction.

Radical change? From BT? Yes of course, credit where it's due! BT is the first national telco in the world to commit entirely to a soft (non circuit-switched) network, meaning we need to examine the nature of this step change, its technical implications and the likely impact on us as users.

Mark my words, this announcement must be recognised as a defining moment, as significant as the change from analogue to digital. Sure, the immediate impact will be slight, simply because the transition for users has to be seamless and gradual, maintaining provision for "legacy" customer premises equipment and services.

Nevertheless, this cannot obscure the fact that today's times are the last throes for circuit-switched communication, a technology at the heart of communication since Cooke and Wheatstone's electric telegraph of the 1830s. This is also the dawn of an era of new service offerings unfettered by narrowband, fixed line technology constraints. However fanciful it may sound, this really is big news. Unconvinced? Let's see . . .

Building Strategy

The strategy behind building 21CN is to migrate voice, data and Internet services to one single, advanced system. The new network treats voice traffic, video, fax and computer-to-computer communication all as data in a single Internet Protocol (IP) format. This data will cross the network using packet technology over virtual or "soft" connections rather than the circuit-switched technology used on today's public switched telephone network (PSTN).

There will be no telephone exchanges as such, but multimedia "softswitches", supporting a range of broadband and narrowband access technologies, will connect calls, which will be delivered to subscribers through multi-service access nodes (MSANs). Marconi is supplying the softswitches and the MSANs and there will be far fewer of them than there are telephone exchanges at present.

The simplified architecture of the new network will also bring up to 15 per cent reduction in the 73 million wire and 400,000 fibre connections in BT's network, plus up to 70 per cent reduction of 100,000 termination points. Fewer "wires and boxes" will mean simpler service management, reduced fault liability, less power consumption and significant cost reduction, along with faster service activation, enhanced test access and better resource utilisation. On this BT justifies its claims to a richer customer experience and substantial operational savings.

21CN, says BT, will give users the same kind of personal configuration of their telecomms facilities as they have over desktop PC applications. You will be able to control provision of your services online at any time of day or night, fine-tuned with the exact features and facilities you want, to help you work smarter and more creatively. BT's "ubiquity" offerings will make flexible working from home an option for more people, cutting costs and making for better quality of life.

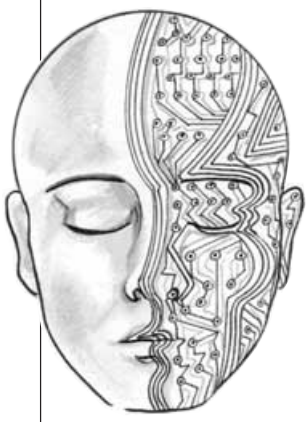
Attractive leisure services enabled by broadband will bring into the house more entertainment and support for hobby activities, allowing home life to expand where people want it. Putting more things under your control (video on demand, online shopping and home banking are only three examples) will help put the balance back into life. And it's all coming to your telephone line very soon (starting 2006).

Death Knell for Dial Phones

One minor casualty of the new network is the humble dial telephone that some of us still use. Whilst the new MSAN access hub mentioned above has interfaces for conventional POTS telephones (not to mention all sorts of broadband and optical fibre connections as well), it will recognise only tone dialling telephones. The old loop-disconnect or pulse signalling used in phones fitted with dials and first-generation push-button keypads will not be recognised and BT will have to contact all subscribers to make sure they are aware of the change. The timetable states that migration to the new network will begin in 2006, with most users transferred two years later.

Diehard dial fans need not worry, however, as adapters will be available, and a simple and effective solution is already on sale in the USA. It's a matchbox-sized converter that plugs in series between your telephone's line cord and the phone socket. It is designed for the U.S. (Western Electric, RJ-11) plugs and sockets but that's a minor problem.

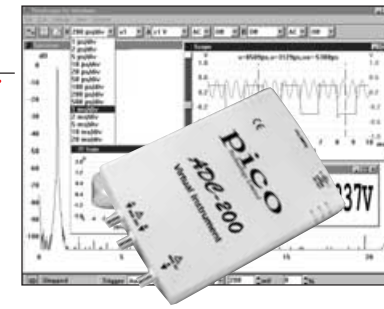
On incoming calls it does not interfere in any way. On outgoing calls it recognises each digit dialled and sends the appropriate touch-tone signal in the short pause between each digit. Obviously you can use it only on lines that recognise tones only; if you used it on a normal BT line you would get wrong numbers because the exchange would recognise both the pulse and tone signals for each digit dialled. You can see the product at **http://www.sandman.com/pdf/page91. pdf**; the order reference is CID6K.



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Betty's Flasher – Kindly Light

AN elderly woman in our congregation had an l.e.d. flasher on her garage door to put fear into would-be thieves. Unfortunately, one of said thieves stole the l.e.d. flasher. Could I make her a new one? So I designed this one from scratch, which will theoretically flash brightly for more than ten years, and is named after her!

L.E.D. flashers seldom last for more than one year off AA batteries – the once-popular LM3909 flasher being a well-known example. On the other hand, the l.e.d. flasher shown in circuit diagram Fig.1 will flash an ultrabright l.e.d. brightly for ten years or more off three alkaline AA batteries.

The circuit uses an *RC* oscillator based on a single gate, IC1a, of a CMOS 4093 Schmitt trigger quad NAND gate. However, instead of wiring l.e.d. D2 from the output of IC1a to one of the power rails, as is frequently done, D2 is placed in capacitor C1's discharge path instead. That is, capacitor C1 discharges through l.e.d. D2 and resistor R2. Thus l.e.d. D2 is powered directly by the capacitor.

Since C1 charges through R1 and D1, the circuit's power consumption is essentially determined by the value of resistor R1 – plus the "overhead" of IC1, which is almost negligible at 2μA to 3μA. With a value of 220kΩ for R1 at 4·5V, this means that C1 draws little more than 20μA.

Quality alkaline batteries have a capacity rating of around 2·6Ah, so that a further calculation of 2·6Ah / (20 + 3μA) reveals that the flasher is destined in theory to work for more than 13 years off one set of batteries. The flash rate is about 1Hz.

Power may further be conserved by increasing the value of R1 to 470kΩ and reducing C1 to 4·7μF. This would offer a 20-year flasher, if the batteries were theoretically perfect, and the flash would still be fairly respectable. Note that other makes of 4093 i.c. may change the characteristics of the flasher.

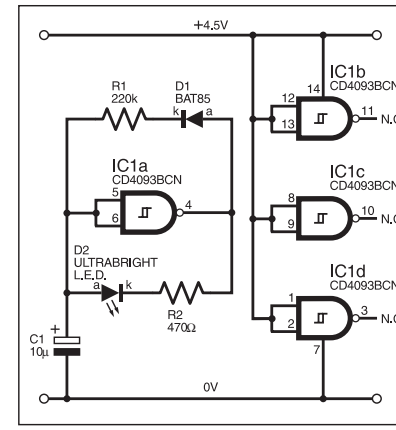


Fig.1. Betty's L.E.D. Flasher circuit diagram.

Thomas Scarborough, Cape Town, South Africa

Water Safety Interlock – Flood Barrier

THE interlock circuit diagram shown in Fig.2 disconnects a water pump and itself from the mains electricity supply as soon as the water rises to a predefined level, as set by the positioning of sensor probes A and B.

The sensors, which can be household pins or iron nails, are held suspended in the tank at a level just below the water overflow outlet. Pressing push-to-make switch S1 energizes relay RLB and turns on the mains a.c. supply to the water pump and sensing circuit.

Initially, with the water level below the sensors, *npn* transistor TR1 (a BC184, BC548 or similar device) is turned off and relay RLA is not energized, with its normally-closed (n.c.) contacts closed and so conducting current to RLB and turning it on. In this condition, RLB's normally-open (n.o.) contacts are closed and current flows to the water pump. Thus water flows into the water tank.

As soon as water touches across both sensors, transistor TR1 is turned on, thereby energizing RLA, whose contacts now open. As a result RLB turns off, its contacts open and the pump and the circuit turn off again. They remains off until switch S1 is pressed again, causing the cycle to repeat.

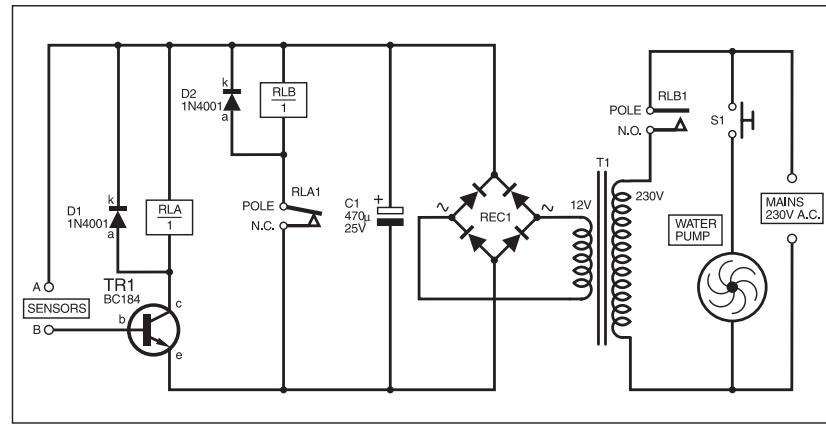


Fig.2. Circuit diagram for a Water Safety Interlock.

This mains electricity circuit must only be constructed by those who are suitably qualified or supervised.

Ejaz ur Rehman, Islamabad, Pakistan

Audio Frequency Synthesiser – Squaring Up and Down

A SIMPLE way of generating a very stable and accurate audio frequency is to use a crystal oscillator followed by a programmable divider circuit. The circuit diagram shown in Fig.3 does just this.

Inverting gate IC1a is used as a crystal-controlled oscillator whose output is buffered by IC1b and fed to the clock (CK) input of the 12-stage binary counter, IC2, used as a variable divider. The number that the frequency is to be divided by is set by switches S1 to S12, and can be any value between 1 and 4095, the switch settings representing the division number in binary form.

In conjunction with switches S1 to S12 and resistor R4, diodes D1 to D12 perform a NAND gate function having up to 12 inputs. Via the double inversion provided by IC1e and IC1f, the NAND gate's output controls the counter's reset pin (MR). When the count value at outputs Q0 to Q11 reaches the value selected via the switches, the NAND gate function goes high and the counter is reset. IC1e and IC1f improve the pulse shape.

On the low-to-high transition, the reset pulse from IC1f can be used to trigger JK flip-flop IC3b via switch S13, to provide a 1:1 mark-space ratio pulse from IC3b output Q, dividing the frequency by a further two in the process. The pulse from this output is fed to the combined bases (b) of transistors TR1 and TR2 used as output drivers, which provide the first of two outputs from the synthesiser, buffered by resistor R6 (limiting current to 100mA max.).

This output frequency may be further divided by two, by being triggered from output $\overline{Q}$ of flip-flop IC3a, as selected by switch S13. This gives a total division ratio of up to 16,384, giving a minimum output frequency of 61Hz when using a 1MHz crystal. The second, anti-phase, output is via transistor pair TR3 and TR4, under control of IC3b output pin $\overline{Q2}$.

One measure of the quality of a frequency synthesizer is its step size – that is, how big the frequency change is from one setting to the next. In this circuit the division ratio changes in steps of two or four due to IC3a and IC3b, so the step size is two or four times the calculated figure.

Using a 1MHz clock and with IC3b clocked directly by the reset pulse, the following is a selection of approximate step sizes:

Frequency	*Step Size*
500Hz	0·5Hz
1kHz	2Hz
2kHz	8Hz
10kHz	200Hz
50kHz	5kHz

A way of adding more steps is to get the divider to divide by a different number (n+1) on the marks rather than on the spaces. This results in an asymmetrical output waveform, but it gives 50% more steps. The method will only work with even division ratios in the divider circuit, as switch S1 must be in the open position (this is why there is a 50% increase rather than 100%).

The function that achieves this is formed around IC1c, IC1d and associated components. Counter output Q0 is buffered by IC1c whose output feeds into the discrete NAND gate formed by resistor R5 and diodes D16 and D17. When IC3a output Q1 is high, pulses from IC1c trigger IC1d, whose output then triggers the common reset connection via diode 19.

However, when IC3a pin Q1 is low, the input to IC1d is held low and cannot respond to pulses from IC1c, consequently the reset line cannot be triggered high by IC1d, thereby increasing the division ratio by one. This function can itself be inhibited, via diode D18 and switch S14.

Be aware that although the circuit works faultlessly with a 1MHz crystal, it was found that it worked very poorly and intermittently with a 4MHz crystal. The prototype was powered by a mains adaptor supplying 12V at up to 250mA.

P. A. Tomlinson,
Hull

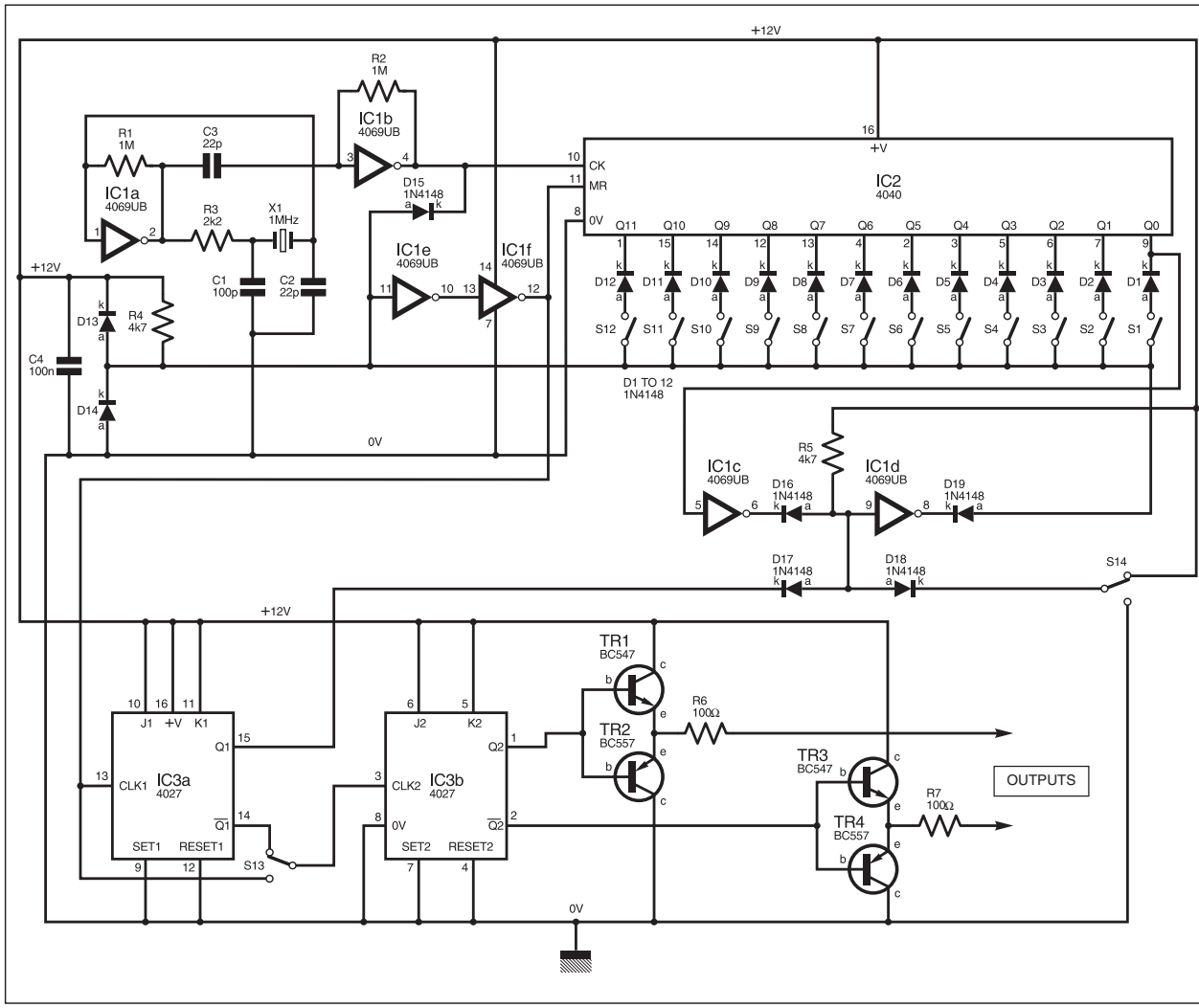


Fig.3. Circuit diagram for an Audio Frequency Synthesiser.

Line-O-Light – Eternal Light!

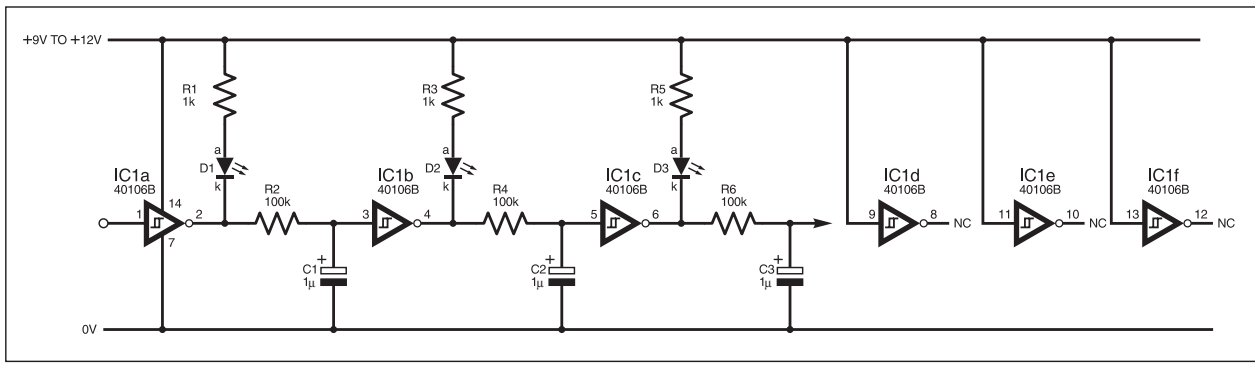


Fig.4. Circuit diagram for the Line-O-Light.

THE circuit in Fig.4 represents a simple "Line-O-Light" which may be infinitely extended.

As things stand in Fig.4, if the junction of resistor R6 and capacitor C3 is wired back to the input at IC1a pin 1, one to two l.e.d.s will illuminate simultaneously in sequence. However, this sequence may be lengthened at will, with two more Schmitt inverter gates being inserted into the sequence each time. In this case, one more l.e.d. lights up for every two gates added. For instance, if a total of five gates were used, two to three l.e.d.s in the sequence would illuminate at the same time.

Described in brief, the charge on the capacitors is shunted round and round the "circle", to illuminate l.e.d. after l.e.d. Each capacitor is charged through its attendant resistor. As the charge on the capacitor at a gate's input goes high, so the gate's output goes low, with the result that the following capacitor begins to discharge, and so on.

On the surface of it, it might seem that the same would be accomplished with a simple flip-flop flashing l.e.d.s alternately. However, the average number of l.e.d.s which light in this circuit is the number of gates divided by two. With a flip-flop, it would be the number of *l.e.d.s* divided by two. This makes for a slightly different effect.

Also, if the value of one of the capacitors in this circuit is increased, a periodic delay is introduced into the Line-O-Light. Further effects may be achieved by charging or discharging the capacitors more rapidly through resistor-diode combinations, or by wiring a resistor of one's choice from any output to any input.

As the circuit stands, the illuminated l.e.d.s are shunted round the "circle" at about 1Hz. This may be changed by changing the values of the capacitors or their attendant resistors.

Thomas Scarborough,
Cape Town, South Africa

Automatic Morse Beacons – Keying the Flightpath

AS part of a larger flight simulation project, emulating an ILS (Instrument Landing System) marker beacon, the possible code sequences embedded in a standard binary count were explored. It was found possible to generate continuous dots, continuous dashes or continuous dot-dash pairs, all with correct Morse spacing (one dash equals three dot lengths, one inter-symbol space equals one dot length). As the sequence generators are driven by a common clock, all Morse outputs will be at the same speed.

The technique explained here and shown in Fig.5 might stimulate readers into looking at binary sequences to obtain other patterns needed for logic or Morse purposes. It uses two 74LS163 synchronous binary counters, IC1 and IC3, and a NAND gate, IC2a.

The input clock signal triggers IC1 and IC3 to step through their 4-bit sequences. In fact, only parts of the sequences are needed. Taking the repeated dot-dash pairs from IC1, these occur at decimal steps 11, 12, 13, 14, 15, 0. In binary, and in order of outputs QD, QC, QB, QA, this is 1011, 1100, 1101, 1110, 1111, 0000.

Feeding the rightmost two least significant bits at QA and QB into NAND gate IC2a, where "any low gives a high", the input/output sequence becomes:

B A	*NAND*
1 1	0
0 0	1
0 1	1
1 0	1
1 1	0
0 0	1

Therefore, a correct sequence with a space (one time period), a dash (three time periods), another space and then a dot (one time period) is generated at IC2a output pin 3. To make this sequence cycle back to the beginning, IC1's synchronous load pin 9 is activated by the leftmost, most significant bit, QD. Looking at the 4-bit sequence, bit QD is 1 at all times, except for the very last member of that sequence. So, on the next clock pulse after bit QD pulls the load pin low, IC1's input registers are loaded with the logic levels on their pins, in this case loading the binary value 1011, as required at the start of the 4-bit sequence.

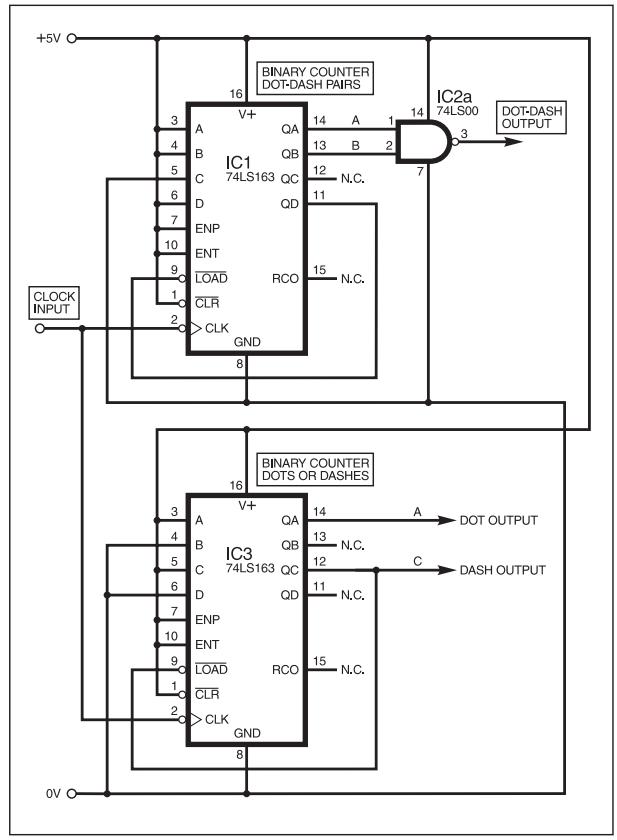


Fig.5. Automatic Morse Beacons circuit diagram.

The other sequence, a dash of three periods followed by a single-period space (the length of a dot), is found at IC3 output pin QC. Looking at the four-bit sequence for decimal values 5, 6, 7, 8 gives:

D	*C*	*B*	*A*
0	1	0	1
0	1	1	0
0	1	1	1
1	0	0	0

This has been tabulated so as to emphasise bit C. Note the three 1s, representing the correct dash sequence, and then a 0, in the right place to force a synchronous re-load of input logic 0101 on the next clock cycle.

For continuous dots, look at bit A in the above sequence. On the first clock pulse, bit A changes state (say from off to on), on the second pulse it reverts. So the clock will run at twice the symbol rate of the required Morse and this applies to all sequences.

Note that the 74LS163 loads synchronously, at the end of each cycle.

Godfrey Manning G4GLM,
Edgware, Middx

Fine-Tuning for DC Receivers – Potted Improvement

THE sensitivity and constructional simplicity of Direct-Conversion (D.C.) h.f. receivers has seen the publication of numerous circuits, and the commercial production of many radio-kits. Their popularity is well- justified by excellence of performance, except for one important aspect of those circuits which use a varactor diode as the main-tuning element. All too often, resolution of SSB and CW (single-sideband and continuous wave) signals is extremely difficult because of the relatively coarse frequency-control provided by the potentiometer used as the main tuner, such as shown in Fig.6a.

The simple and low-cost modification shown in Fig.6b remedies that problem, by adding a low-value variable-resistor in series with the main-tuning potentiometer to act as a fine-tuner. A 1kΩ linear potentiometer, VR2, with a 470Ω fixed resistor, R2, connected directly in parallel, effectively makes a variable resistor whose value changes from a few ohms to about 320Ω as the spindle is rotated. When connected as shown in Fig.6b, the very effective fine-tuning control so produced really takes the sting out of resolving SSB signals, and the winkling-out of CW signals.

To do this, first make the fine-tuner control by soldering the 470Ω resistor across the two outer tags of the 1kΩ linear potentiometer, then solder to it two short lengths of PVC-covered wire, one to an outer tag and one bridging the centre tag to the other outer tag. Now cut the zero-volt connecting wire of the main tuning potentiometer where shown in Fig.6a, and solder the two fine-tuner wires to where the cut was made. Unlike a tuning-capacitor, this type of tuning-control is not in itself frequency-sensitive, hence screening is not vital so it could be used experimentally without the receiver.

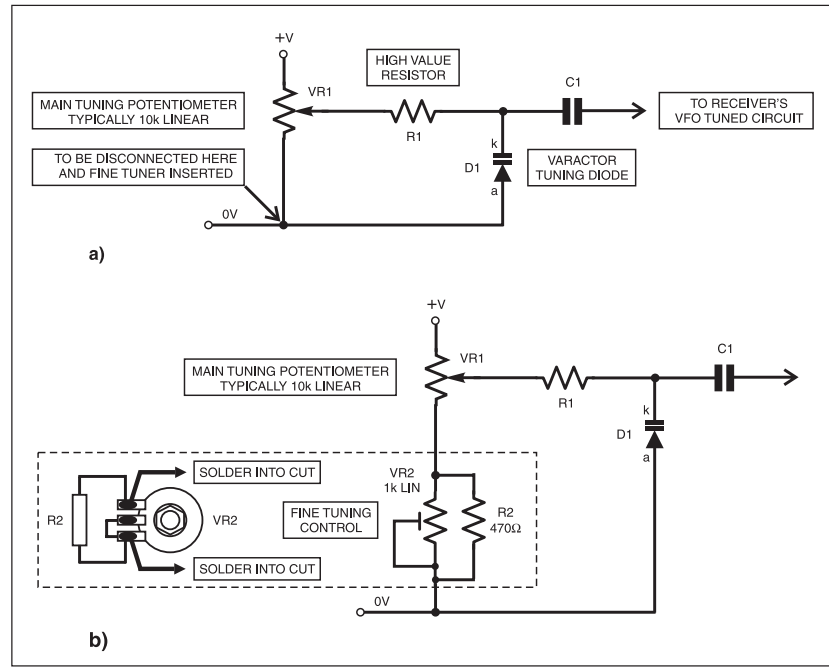


Fig.6. Adding fine tuning to Direct Conversion receivers. a) Typical varactor tuning circuit and b) suggested amendment to provide easier fine tuning.

Edwin Chicken G3BIK.
Morpeth, Northumberland

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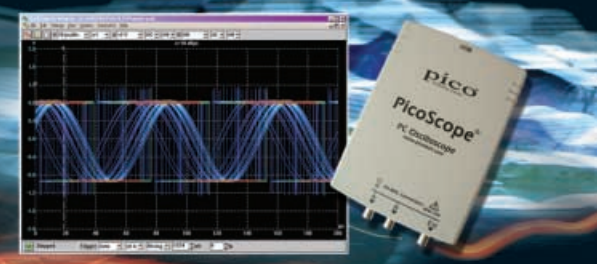
IU is *your* forum where you can offer other readers the benefit of your Ingenuity. Share those ideas, earn some cash and possibly a prize!



PicoScope 3000 Series
PC Oscilloscopes

The PicoScope 3000 series oscilloscopes are the latest offerings from the market leader in PC oscilloscopes combining high bandwidths with large record memories. Using the latest advances in low power electronics, the oscilloscopes draw their power from the USB port of any modern PC, eliminating the need for mains power.

- High performance: 10GS/s sampling rate & 200MHz bandwidth
- 1MB buffer memory
- Advanced display & trigger modes
- Compact & portable
- Supplied with PicoScope (oscilloscope/spectrum analyser) & PicoLog (data acquisition) software.



PicoScope	3204	3205	3206
Bandwidth	50MHz	100MHz	200MHz
Sampling rate (repetitive)	2.5GS/s	5GS/s	10GS/s
Sampling rate (single shot)	50MS/s	100MS/s	200MS/s
Channels	2+Ext trigger	2+Ext trigger/Sig gen	2+Ext trigger/Sig gen
Oscilloscope timebases	5ns/div to 50s/div	2ns/div to 50s/div	1ns/div to 50s/div
Timebase accuracy	50ppm	50ppm	50ppm
Spectrum ranges	0 to 25MHz	0 to 50MHz	0 to 100MHz
Record length	256K	512K	1MB
Resolution accuracy	8 bits / 3%		
Ranges	10mV to 2V/div		
PC Connection/Power supply	USB2.0 (USB1.1 compatible)		

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News . . .

A roundup of the latest Everyday News from the world of electronics

CHARGED CABLES FOR AUDIOPHILES

Skeptics, look away now – Barry Fox's story is not for you!

JAPANESE electronics specialist Marantz has a marketing partnership with US connector cable company AudioQuest, and Joe Harley of VP Product Development was present in Barcelona recently at a trade seminar to unveil a new system called DBS, Dielectric Bias System. Developed by AQ founder Bill Low and Richard Vandersteen, DBS claims to improve the sound of a hi-fi system by turning speaker and component connecting cables into electrically charged capacitors

The idea, says Harley, comes from the question which AudioQuest thinks needs answering – "why does my hi-fi system sound better after it has been switched on for several hours". AQ's suggested answer is "because the cables gather a d.c. electrical bias charge".

Core of the Solution

The new cable has an extra central core which is connected to the positive terminal of a small 36V battery pack, with the negative terminal connected to the outer shield. "There is no current drain so batteries last as long as if they were on the shelf," says Harley.

"It takes about two days for the dielectric charge to build up. The effect is that the system sounds fundamentally better. I see it as an audio no-brainer. It's a major leap forward and a number one sonic influence."

Seen but not Heard

The effect cannot be demonstrated by switching the battery on and off because of the long charge-up time, so AQ is offering journalists matched pairs of cables with and without batteries. There is a practical problem, says Harley. "Airport X-ray machines pick up the cables as a coil of thick wire with battery pack, and you get surrounded by security guards".

Every Marantz seminar ends with a demonstration by Ken Ishiwata of music played through high-end Marantz components. This year he used DBS interconnects with an SA11 SACD player, PM11 amp and Mordaunt Short Performance speakers. Unfortunately there was no opportunity to switch between DBS with and without power. So the press never did get the chance to hear whether the dramatic advantages claimed by AudioQuest are clearly audible.

Kent Electronics Course

DR KEN SMITH G3JIX tells us that he intends to run a course in the Canterbury, East Kent, area on electronics and radio, which will cover the new Advanced Radio Amateurs' syllabus, as well as a few more general electronics principles. The course is planned for September next and will offer some practical "hands-on" experience in project building.

With some subsidiary work, the course will lead interested students to the Advanced Radio certificate. It will also be valuable for junior staff and apprentices in local electronics and radio companies, as well as people interested in electronics generally.

Dr Ken Smith is well known for his tutorial work in electronics, history of radio, astronomy etc. Initial enquiries should be sent to him:

K. L. Smith G3JIX, Staple Farmhouse, Staple, Canterbury, Kent CT3 1JX. Tel: 01304 813175. Email: g3jix@aol.com.

AUTUMN NVCF SHOW

THE autumn *National Vintage Communications Fair* (NVCF) takes place on Sunday 10 October 2004 at Hall 11, NEC, Birmingham. Doors open 10.30 a.m. to 4 p.m., admission £5 (under-14s free). Early entry, from about 8.30 a.m., admission £20. All tickets (on the door). Admission includes a free 32-page "Collectors' Guide" (while stocks last). Car parking charges apply.

The October show sees a major display being staged, celebrating the "One Hundredth Birthday" of the thermionic valve with over 400 valves on display.

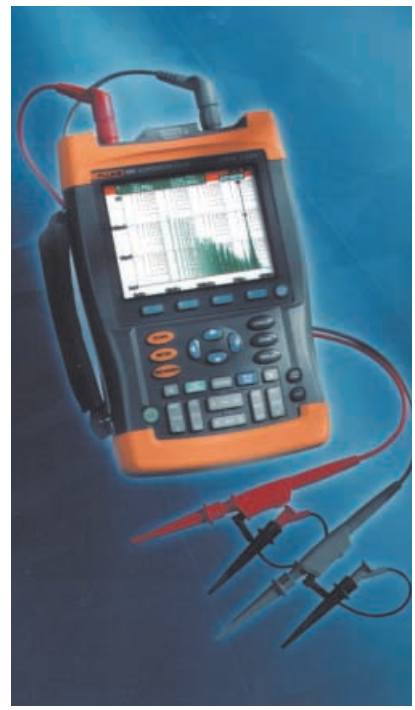
For more information contact NVCF, 122B Cannon Street Road, Whitechapel, London E1 2LH.

Tel: 07947 460161.

Email: info@nvcf.org.uk.

Web: www.bvws.org.uk.

HANDHELD SCOPE



FLUKE has announced new enhancements to its dual-input ScopeMeter 190 series of handheld oscilloscopes. Increasing their power to analyse signals, all the colour and monochrome models of these scopes now offer increased waveform resolution. The 190C colour models also include frequency spectrum analysis using Fast Fourier Transformation (FFT) analysis as a standard feature.

This battery-powered series offers up to 200MHz bandwidth and 2·5GS/s real-time sampling rates. The waveform memories have been increased by 150%, now allowing 3000 samples per channel to be acquired. This greatly increased waveform resolution can be used with the new 16x zoom function to find tiny details in a waveform.

For more information contact Fluke (UK) Ltd., Dept EPE, 52 Hurricane Way, Norwich, Norfolk NR6 6JB.

Tel: 0207 942 0700

Fax 0207 942 0701.

Web: www.fluke.co.uk.

CHIPPED DIAMONDS

Diamonds are a microchip's new best friend, says Barry Fox.

IF chips in an electrical device get too hot, their life shortens. A metal heatsink can suck heat from the air inside a device and transfer it to the air outside, but the heat must first be spread from the chips to the sink. Metal is no good for this because it short circuits the electrics.

Element Six of the Isle of Man is now patenting a new way to use diamond, which is a good electrical insulator and moves heat efficiently because the crystal lattice vibrates (WO 2004/34466). The new heat spreader is affordable – especially for mission-critical circuits – because the diamond layer is only 10 micrometres thick, made by vapour-deposition from very hot hydrocarbon, such as methane, and hydrogen.

The trick is to deposit the film on a silicon support that is peppered with partly embedded low grade diamond grit particles. The protruding tips of the grits provide a strong bond for the smooth thin film. Heat streams from the chip through the film to the sink, keeping the chip cool.

Vintage Museums

OUR attention has been drawn to two museums in the West of England. The information came in a leaflet entitled *A Guide for Enthusiasts of Vintage Radio in the West*.

Montacute TV and Radio Memorabilia Museum is the first highlighted. It offers "a nostalgic trip through the world of radio and TV with a collection of radios from vintage wirelesses to novelty transistors and an extensive range of memorabilia, games, books and toys. It featured on BBC's *Antique Inspectors* and Channel 4's *Collectors Lot*!

It is open from Easter until the end of October, daily and Saturdays 10 to 5, Sundays 10.30 or 12 to 5.30 (closed Tuesdays early April and October). Phone for details of winter opening.

The other is described as Washford's unique Radio Museum, which is housed in part of a listed 1930s BBC transmitting station "a fascinating and nostalgic experience of broadcasting history situated within Tropiquaria".

Its address is Tropiquaria, Washford Cross, Watchet, W. Somerset TA23 0JX. Tel: 01984 640688.

Email: tropical@golobalnet.co.uk.

Web: **www.tropiquaria.co.uk**.

Stewart's Move

STEWART of Reading, renowned suppliers of guaranteed used equipment, tell us that they have moved. Their new address is Dept EPE, 17A King Street, Mortimer, Nr Reading RG7 3RS. Tel: 0118 933 1111. Fax: 0118 933 2375.

Web: **www.stewart-of-reading.co.uk**.

Bletchley Park's New Exhibition

BLETCHLEY Park, also known as Station X, was the site of the British successful attempts to crack Nazi cyphers during World War 2. The new exhibition tells the true and complete story of Bletchley Park's WW2 code breaking, which historians think shortened the war by two years.

On public display for the first time is a piece of an original Colossus, the worlds first semi-programmable electronic computer, developed for Bletchley Park. The exhibition begins with a timeline and a children's cartoon history of Bletchley Park and includes an interactive display of a German U-boat Enigma station, a "Y" (radio listening) station and a four-rotor (coding wheel) Enigma machine.

Bletchley Park's Chief Patron, HRH Duke of Kent KG, opened *The Bletchley Park Story* on 10 June, in phase one of the National Code Centre's new exhibition complex, Block B, which is a wartime building overlooking the Park's lake.

The new official filmed history of Bletchley Park, *Churchill's Secret Passion*, gives the inside story by the people who worked there.

Bletchley Park is at Milton Keynes MK3 6EB. Open daily. Tel: 01908 647269.

Web: **www.bletchleypark.org.uk**.

Mobilising Research Funds

WE have been contacted by the Roy Castle Lung Cancer Foundation who tell us that old mobile phones and empty printer cartridges can be recycled and the proceeds used to help fund vital research into the early detection, diagnosis and treatment of lung cancer. If you have any such items lurking around at home or at work, you are invited to send them to:

Roy Castle Recycling Appeal (EL), 31-37 Etna Road, Falkirk FK2 9EG. For more details visit **www.recyclingappeal.com/roycastle**, or phone 08712 505050.

ROBOTIC GAMES

UK Robotics have recently launched an exciting new national competition, UK Robot Games, and will be attending the *Design & Technology* show at the NEC, Birmingham in November. They will be displaying a variety of robotic projects, including some that have appeared on a number of TV shows, plus creations brought along from a number of invited schools, and there will be live demonstrations. The aim of the show is to get schools interested in building robotic creations and compete in the larger national competition.

The games are a contest for home-made machines that walk, swim, jump, climb, solve mazes, fight, race, play football and even box. Trophies will be presented for interesting designs and for winning robots in the various categories. The tournament is designed to stimulate interest from young people in science and technology. However, it is open to all and will be held in regions all over the UK in the spring of 2005, culminating with a grand final in the summer.

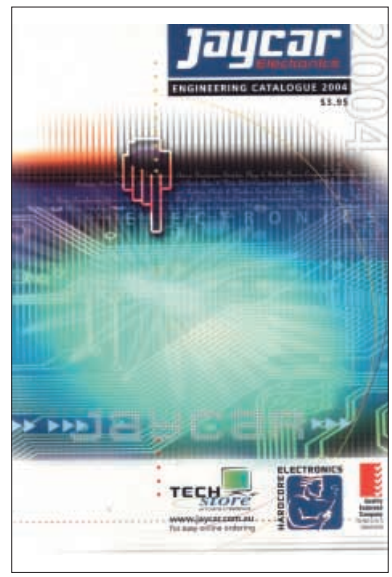
The games have been organised by a group of robot enthusiasts whose creations have appeared on TV programs like *Robot Wars* and *Technogames*. Representatives from Antex, Technobots, and Roaming Robots, who are sponsoring the stand, will be in attendance to help schools with any questions.

For more information, and the rules for entering the competition, browse **www.ukroboticgames.org**.

EVENT HORIZON

THERE are many events that deserve publicising here – radio fairs, auctions, general gatherings, and even news about local electronics clubs. If you would like to offer us something newsworthy for possible inclusion in this section, drop us a line or email us. Remember though that we need material in at least a month before we are due to go to press with the next issue.

JAYCAR'S CAT



WE have received (thumping on the News Desk!) Jaycar's 400+ page catalogue. Jaycar are a well-established Australian company and have produced the catalogue with prices shown in pounds Sterling, making it simple to order and pay for goods direct from the UK! Their secure on-line ordering system also ensures that your ordering is safe and secure.

The catalogue is crammed with over 6000 products, ranging across what appears to be the full "alphabet" of electronic categories, from ABS cases, computer accessories and electronic components, through kits, semiconductors and TV accessories, to ZIF sockets and even zoom lens.

You can request a *free* copy by logging on to Jaycar's website at **www.jarcar-electronics.co.uk/catalogue**. Their postal contact details are: Jaycar Electronics, Dept EPE, 100 Silverwater Road, Silverwater, NSW 2128, Sydney, Australia. Tel: 0800 032 7421.

Constructional Project

Radio Control Failsafe



Ken Ginn

Senses failure of the RC system and renders the model motionless and safe, can be linked to almost any land-based RC model.

THIS failsafe unit was developed for use in radio control (RC) models, originally for combat robots, but it can be applied to any land-based RC model. There is a statutory requirement for such a failsafe device, in particular with the rules associated with the use of fighting robots. The safety aspect is, of course, of paramount importance.

In RC systems, especially when there is a fault, such as in the case of the loss of transmitter signal at the receiver, the effect could be to send the robot or model into uncontrollable action and cause damage to property, the model itself, or indeed to bystanders.

This unit is designed to sense the moment of failure of the RC system and put the robot or model into a safe condition, rendering it motionless.

There are commercial failsafes on the market, but they only provide a settable pulse width output during the failure of the system. This steady signal is used to provide a stable failsafe pulse to the model's speed controller during a loss of signal.

This failsafe unit is "transparent" during normal operation. During a fail situation it provides the servo or speed controller with a reliable and steady train of pulses, the value of which is set by a preset potentiometer. When the unit is used with a speed controller, on a model boat for instance, the latter's supply can be switched off via a relay during failsafe, and the controller put into neutral – a belt and braces approach maybe, but it is better to err on the side of caution!

Radio Control Format

What we have to consider regarding the RC format, is the signal being received from the model. Under normal operating conditions the attached servo will respond to the position on the transmitter's joystick. Coupling an oscilloscope to a receiver's servo output we would see a positive-edged pulse having a duration in the range of 1·0ms to 2·0ms, repeating every 20ms or so – i.e. updated about fifty times per second.

The actual pulse width duration will depend upon the joystick's position. Any pulse received by the radio receiver servo output which is outside the set parameters should cause a failsafe condition to occur. Usually this would be caused by very short duration pulses, typically less than 1·0ms, rather than anything greater than 2·0ms.

When monitoring the servo output of an RC receiver during a transmitter failure, a series of short pulses will be seen, usually of about 30μs to 50μs duration, and caused purely by noise from receiver. They are well out of the normal operating range of a servo or speed controller, and will most certainly result in erroneous actions.

Observing the actions of a servo under these conditions, the output arm of the servo will be seen to be twitching. In the case of a speed controller, the motor may spontaneously power up in forward or reverse.

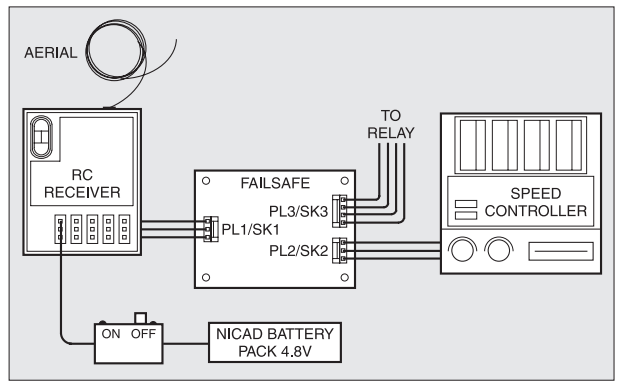


Fig.1. System schematic diagram for the Radio Control Failsafe.

Failsafe Circuit

As shown in Fig.1, the failsafe unit is connected between the RC receiver and the associated circuitry, such as a speed controller. Power to the failsafe unit is supplied by the receiver.

The complete circuit diagram for the Radio Control Failsafe is shown in Fig.2. At the heart of the circuit is a PIC16F84A-10 microcontroller, IC1. This is operated at 10MHz, as set by crystal X1.

The circuit is connected to the RC Receiver via plug PL1, through which power is supplied, plus the control signal. In the positive power line from PL1 pin 1, resistor R3 and diode D2 are included to protect the PIC against power line transients.

The signal from PL1 pin 2 is fed to PIC pin RB3, which is configured as an input. Resistor R1 biases RB3 low in the absence of an input signal. The combination of components VR1, R2 and C1 on PIC pin RB5 allow the software to set a controllable value for the output pulse under the fail conditions.

Light emitting diode D1 will not illuminate under normal operating conditions, but should the pulse width being fed to the unit fall outside what is defined as a valid signal (a pulse width of 1·0ms to 2·0ms) then it will be turned on.

The signal output from the PIC pin RA0 under both valid and fail conditions is fed to plug PL2. Under normal valid signal conditions, PIC pin RA1 is held high, supplying current to optocoupler IC2, so turning on its internal transistor. When an invalid pulse is detected and the unit goes into fail mode, RA1 goes low, turning off the optocoupler.

The output from the optocoupler at its pin 3 controls Darlington transistor TR1, which in turn controls relay RLA1. The relay's switch contacts are connected so that they cut off the power supply to the model's or robot's motors and/or weapon. The maximum relay current permissible by TR1 is approximately 200mA.

Program Operation

Initialisation

When the unit is first switched on there is a built-in delay of two seconds. The Fail l.e.d. (D1) will flash twice, then remain off while the unit is receiving a valid signal. When an invalid signal is received, D1 will flash twice, then remain on, indicating a fail condition.

Running – Valid Pulses

When valid pulses are being received by the unit, they are re-generated at PIC pin RA0 from where they are fed to output plug PL2. Simultaneously, optocoupler IC2 and transistor TR1 are turned on, via PIC pin

RA1, which drives the l.e.d. within IC2, buffered by resistor R7.

Running – Fail Condition

Should the transmitter be switched off during the time the receiver is powered, the Fail l.e.d. will illuminate, indicating the fail condition. The output from RA1 will go low, causing TR1 to turn off, thus de-energising the failsafe relay RLA1.

The output pulse from the unit during the failsafe condition will be stable and have a width set by preset VR1. This is set manually for a pulse width of between 1·0ms and 2·0ms, nominally 1·5ms, see later.

Running and Back-Working

Assume now that a fault has occurred but been fixed and the system is now working as it should. The PIC will see the first valid pulse (again being between 1·0ms and 2·0ms), remain in failsafe mode and start counting the received valid pulses.

Once the counter has reached 100 (taking about two seconds), failsafe mode is exited and normal operation resumed. The signal from the RC receiver is now fed to the speed controller, full control having now been established between the transmitter and the RC model.

Running – Failsafe Mode

When the receiver is not receiving a valid signal from the transmitter, the failsafe will receive a series of short duration pulses. This will be the result of the receiver trying to interpret the r.f. noise received as a valid signal. Since the receiver does not have a squelch circuit, the noise will become random pulses of very short duration.

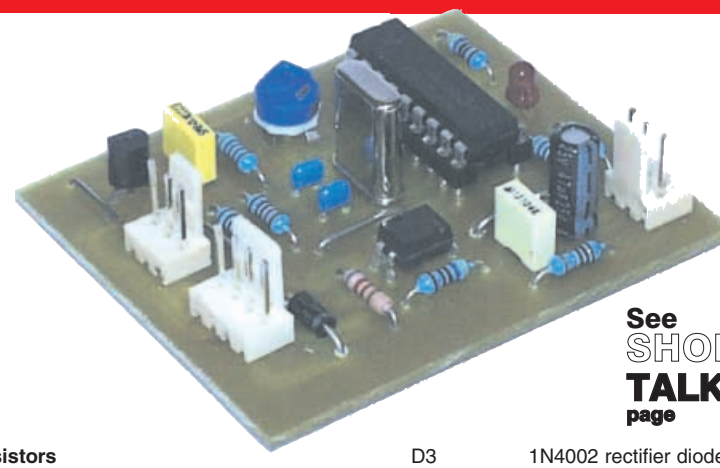
The failsafe circuit will be triggered by these pulses and go immediately into failsafe condition. It will then wait 17ms before looking for another pulse, and checking its validity.

Construction

The unit is built on a single-sided printed circuit board (p.c.b.). This board is

COMPONENTS

Approx. Cost Guidance Only **£16**



See SHOP TALK page

Resistors

R1, R6	100k (2 off)
R2, R4	4k7 (2 off)
R3	1Ω
R5, R7	470Ω
R8	see text
R9	1k

All 0·25W 5% metal film

Potentiometer

VR1	5k preset, min round cermet

Capacitors

C1	22n polyester, 5mm pitch
C2	47μ radial elect. 25V, 2·5mm pitch
C3	100n polyester. 5mm pitch
C4, C5	22p ceramic disc, 2·5mm pitch (2 off)

Semiconductors

D1	red l.e.d., 3mm
D2	5V6 1.3W Zener diode
D3	1N4002 rectifier diode
TR1	BC875 *npn* Darlington transistor
IC1	PIC16F84A-10 microcontroller, pre-programmed, see text
IC2	SHF618-2 4-pin optocoupler

Miscellaneous

X1	10MHz crystal
PL1, PL2	3-pin plug, p.c.b. mounting, 2·5mm pitch (2 off)
PL3	4-pin plug, p.c.b. mounting, 2·5mm pitch
RLA1	5V to 24V d.c. relay (see text)

Printed circuit board, available from the *EPE PCB Service*, code 465; 18-pin d.i.l. socket; connecting cables to suit RC equipment; solder, etc.

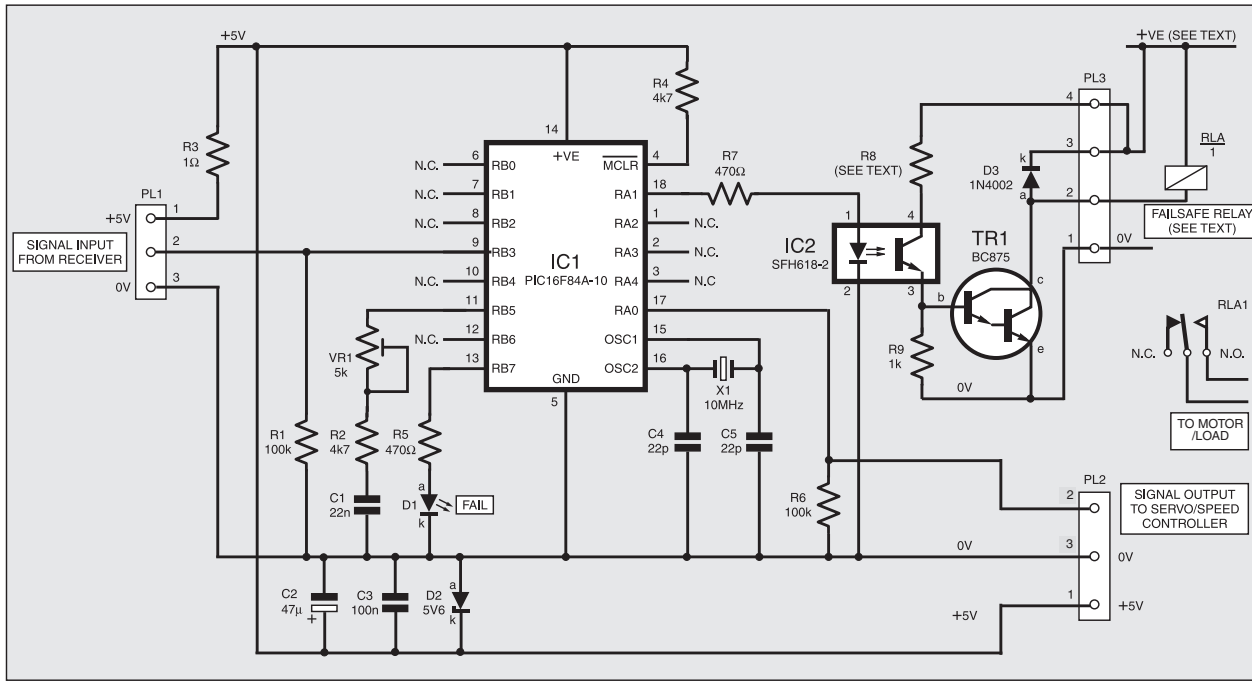


Fig.2. Complete circuit diagram for the Radio Control Failsafe. Note the value of R8 will depend on the supply voltage of the model (5V to 24V d.c.) – see text.

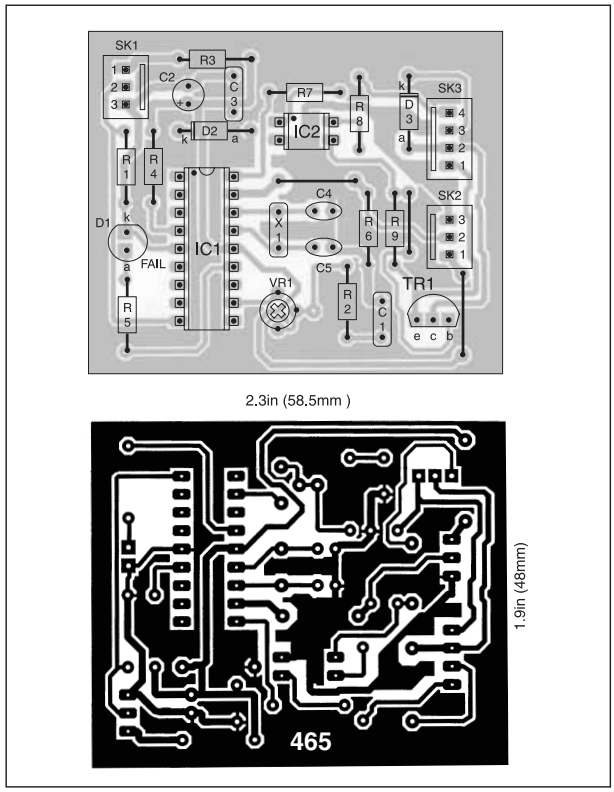
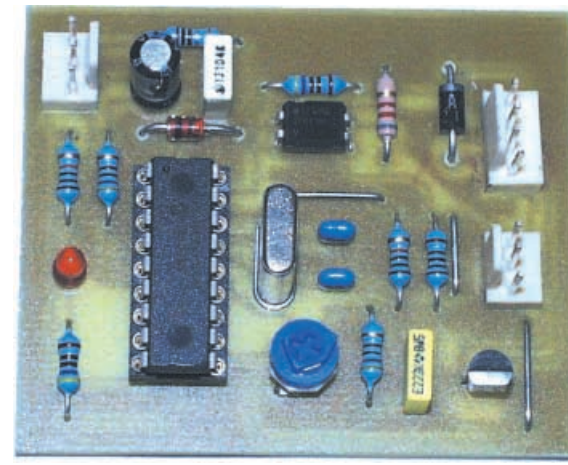


Fig.3. Printed circuit board component layout and full-size underside copper foil master for the Radio Control Failsafe. Note: the "shorts" which appear on some of the pads are thermal relief tracks which connect the pads to the earth plane.



Component layout on the completed Failsafe circuit board.

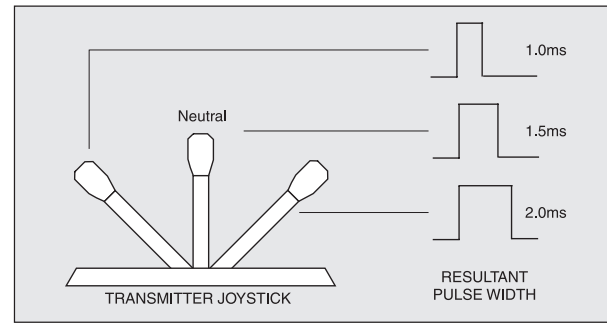


Fig.4. Translation of RC joystick positioning to servo speed control pulse width.

available from the *EPE PCB Service*, code 465. Its component layout and tracking details are shown in Fig.3.

Connections to and from the board are made by three p.c.b. mounted plugs. This facilitates connection to the radio control equipment and the failsafe relay. The relay is not mounted on the p.c.b., but placed in a position best suited to the unit whose power is being controlled. Its contacts should be rated to suit the required current.

The unit can be used to switch 5V, 6V, 12V or 24V d.c. relays, up to a coil current of about 200mA. Because of the choice of supply voltage, the value of resistor R8 has to be selected to supply the correct base bias to transistor TR1. For 5V or 6V operation R8 should be 1k2, for 12V use 3k9, and for 24V use 8k2.

Since the circuit will be subject to a considerable amount of vibration when in use, it would be wise to ensure components are mounted snug against the p.c.b. IC1 must be mounted in a dual-in-line (d.i.l.) socket. In the prototype, optocoupler IC2 was soldered directly to the board, although a d.i.l. socket could be cut to suit it if preferred.

Once the p.c.b. has been assembled, carry out a thorough examination, checking for solder bridges and dry joints, and for incorrect orientation of components such as diodes, capacitors and i.c.s.

Setting Up

Set preset potentiometer VR1 to midway, this should give a "valid" output pulse width at PL2 of approximately 1·5ms.

If possible, connect the completed unit to a bench power supply and raise the supply voltage from zero to 5V, and watch the current drawn from the power supply. At 5V, the current drawn should not exceed 10mA. Switch off the circuit and then switch it back on again. Note that the Fail l.e.d. will wait for two seconds then flash twice to indicate that the unit is initialising. It will then turn on for a third time and remain on, showing the unit has fallen into failsafe mode.

Disconnect the unit from the bench power supply and connect up a transmitter/receiver combo to the unit. Now having control over the pulse width fed to the failsafe, adjust the RC joystick to the central position. Here we shall assume that the generated pulse width is 1·5ms. This can be checked if an oscilloscope is available to calibrate the unit. See Fig.4.

With the transmitter switched off and the receiver powered the failsafe should go through its initialisation routine, with the two second delay before the Fail l.e.d. flashes twice and remains on. But should the transmitter be switched on first, and then the receiver switched on, you will see the l.e.d. flash twice after two seconds, and after finding valid pulses from the receiver, the l.e.d. will remain off. This will indicate that the width of the incoming pulses is correctly between 1·0ms and 2·0ms.

Speed Controller Check

Connect the unit between the RC receiver and a speed controller, the latter powered via the relay. Two choices of connection are shown in Fig.5.

Switch on the transmitter, then the receiver and associated circuitry. Again the Fail l.e.d. will go through its initialisation sequence.

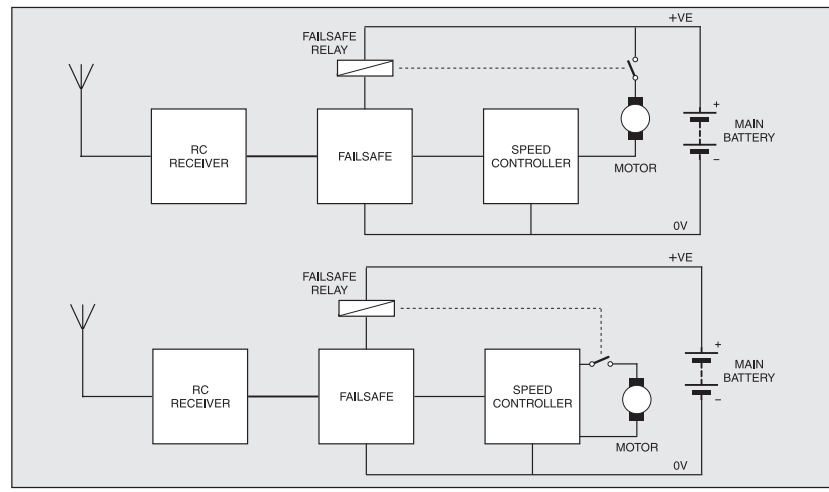


Fig.5. Connection details for linking the failsafe relay to loads.

The pulse width should still be in the region of 1·5ms when the unit goes into failsafe mode. Moving the joystick back and forth through its travel will control the speed controller as per normal. The mid-point joystick position will correspond to the neutral position of the speed controller. So in essence the failsafe unit will not be evident during normal operation.

Ensure that the pulse width produced at each end of the joystick's travel falls within the window of 1·0ms to 2·0ms, otherwise the unit will go into failsafe mode when the speed controller is at full speed forward or reverse, due to the pulse width being outside the valid window.

Switching off the transmitter, the failsafe unit will immediately fall into failsafe mode, and the Fail l.e.d. will illuminate. The speed controller should now come to rest in the neutral position, as set by preset VR1, and the power failsafe relay will now de-energise, turning off power to the speed controller.

Should the speed controller still be active, moving forward or reverse, adjust preset VR1 to trim the speed controller into its neutral position.

Resources

Software, including source code files, for the Radio Controlled Failsafe is available on 3·5inch disk from the Editorial office (a small handling charge applies – see the *EPE PCB Service* page) or it can be downloaded *free* from the *EPE* Downloads page, accessible via the home page at **www.epemag.wimborne.co.uk**. It is held in the PICs folder, under Failsafe.

Caution

The use of radio control models and combat robots can be very dangerous, and adequate precautions must be observed by their builders and operators, who are legally responsible for any injury or damage caused by their models. □



SHOP TALK with David Barrington

Rainbow Lighting Controller

The highbrightness l.e.d.s called up for the *Rainbow Lighting Controller* project came from **Farnell** (☎ ***0870 1200 200*** or ***www.farnellinone.co.uk***). Their order codes are as follows: red, 623-672; green, 302-7752; blue, 366-4569. The article also contains web site details for obtaining the relevant l.e.d. data sheets so readers who wish to use their own l.e.d.s can compare them with the author's.

The lighting enclosure chosen by the author is a "modified" Halfords Ring RL015 reversing-light fitting. Other lighting heads may be used and adapted as appropriate.

You will need to experiment with the positioning of the l.e.d.s within the lighting head to obtain the best effects. In the prototype, due to their narrow viewing angle, the red l.e.d.s were positioned so that one pointed towards the centre back and the other one faced diagonally across the reflector dish.

The frequency of the PIC crystal is not critical and other crystal speeds may be used, particularly the more common 3·2768MHz or 4MHz. The author's crystal is stamped 3·5795MHz.

The power supply can be provided by any mains isolated unit ***intended for outdoor use*** and capable of supplying 12V a.c. at a minimum of about 100mA. The author's p.s.u. is part of an existing commercial lighting set.

For those readers unable to program their own PICs, a ready-programmed PIC16F84A microcontroller can be purchased directly from the author for the sum of £7.50 each inclusive (add £1 for overseas). Orders should be sent to **David Geary, 38 Mayday Gardens, Blackheath, London, SE3 8NN**. Payments should be made out to *David Geary*, in £ sterling *only* and drawn on a British bank.

The software is available on a 3·5in. PC-compatible disk (Disk 7) from the *EPE Editorial Office* for the sum of £3 each (UK), to cover admin costs (for overseas charges see page 665). It is also available for *Free* download from the *EPE* website, accessible via the Downloads click-link on our home page at **www.epemag. wimborne.co.uk** (path **PICs/RainbowLighting**).

Finally, don't forget that the lighting head and finished controller unit need to be completely waterproofed against all the winter elements.

Radio Control Failsafe

The SHF618-2 4-pin optocoupler used in the *Radio Control Failsafe* project was purchased from **Maplin** (☎ ***0870 264 6000*** or ***www.maplin.co.uk***), code CY94C.

Some readers may have difficulty finding the BC875 *npn* Darlington transistor used to drive the low voltage relay. This is currently listed by Maplin (see above), code N55AC. However, there does not appear to be any special technical characteristics about this Darlington device and, no doubt, our component advertisers will be able to suggest a suitable alternative.

The Failsafe p.c.b. is capable of switching 5V, 6V, 12V or 24V d.c.. relays. As the maximum relay coil drive current available from the specified Darlington transistor is restricted to the 200mA mark, it follows that the chosen relay should be capable of operating within this range. Its contacts should, of course, be rated according to the requirements of the model being controlled.

The relay is not mounted directly on the p.c.b. but located in a position best suited to the model being controlled. This also allows for a wider selection of relay as it is "wired" to the board via a plug and socket linking arrangement. The p.c.b. header-pin plugs and matching line socket connectors used should be available from most of our components advertisers.

For those readers unable to program their own PICs, a preprogrammed PIC16F84A-10 microcontroller can be purchased from **Magenta Electronics** (☎ ***01283 565435*** or ***www.magenta2000. co.uk***) for the inclusive price of £5.90 each (overseas add £1 p&p). The software is available on a 3·5in. PC-compatible disk (Disk 7) from the *EPE Editorial Office* for the sum of £3 (UK), to cover admin costs (for overseas charges see page 665). It is also available for *Free* download from the click-link option on the *EPE* home page at **www.epemag.wimborne.co.uk** (take path **PICs/RCfailsafe**).

The printed circuit board is available from the *EPE PCB Service*, code 465 (see page 665).

EPE Wart Zapper

Apart from the important Safety warning (which readers are encouraged to read carefully *before* attempting any treatment), most, if not all, components needed to construct the *EPE Wart Zapper* project should prove to be readily available from our components advertisers.

The pulse switching transistor may be almost any *n*-channel power MOSFET device, such as the BUZ11 or IRF510. The CMOS oscillator i.c. is a standard item from the 4000 series.

The MN21 or 23A keyfob battery should be generally available, you could try your local car spares or photographic shop. Make sure you insert the battery the correct way round, the circuit has no reverse polarity protection.

The small Zapper printed circuit board is available from the *EPE PCB Service*, code 464. The choice and size of plastic box is left to individual preference.

Finally, as stated in the article, the voltage, current, frequency and duration of treatment must not be rashly modified. A year's experimentation and "field" trials lies behind this design.

AlphaMouse Game

The author indicates that a PIC16F627 or 628 microcontroller will run the *AlphaMouse Game* project. For those readers unable to program their own PICs, a "plug-in and go" microcontroller can be purchased from **Magenta Electronics** (☎ ***01283 565435*** or ***www.magenta2000.co.uk***) for the inclusive price of £4.90 each (overseas add £1 p&p).

The software, including source code files, is available on a 3·5in. PC-compatible disk (Disk 7) from the *EPE Editorial Office* for the sum of £3 (UK), to cover admin costs (for overseas charges see page 665). It is also available for *Free* download from the click-link option on the *EPE* home page at **www.epemag.wimborne.co.uk** (take path **PICs/AlphaMouse**).

Stocks of 2-line 16-characters per line alphanumeric l.c.d.s appear to be common lines amongst our advertisers now. (Check the pinouts before wiring-in.) If you wish to use an identical one to the designer, this too came from the above mentioned company.

The printed circuit board is available from the *EPE PCB Service*, code 466 (see page 665).

PLEASE TAKE NOTE

Portable Mini Alarm *(July '04)*

Page 451, Fig.5. The annotations for resistors R4 and R5 on the Sensor p.c.b. component layout diagram should be swapped over to agree with the circuit diagram. Resistor R5 (100k) should be the one that connects to the positive lead of capacitor C3, at the bottom edge of the p.c.b.

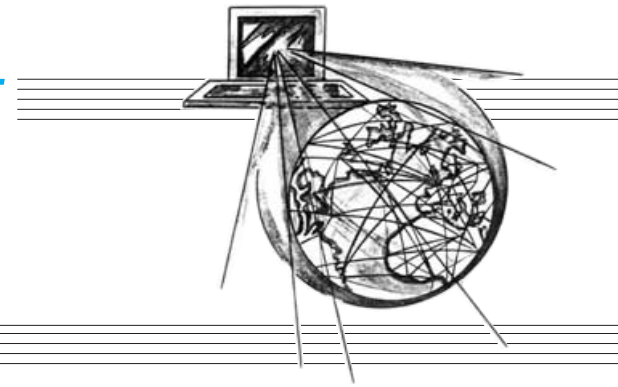
PIC Magnetometry Logger *(July '04* Shoptalk*)*

It has been pointed out that two of the digits in the phone number we gave for Speake & Co, the suppliers of the FGM-3 flux sensors, have become transposed. The correct phone number should be 01600 **78**0150.

SURFING THE INTERNET

NET WORK

ALAN WINSTANLEY



THE latest headlines from the Internet world include details of MSN's redesigned search engine (**www.msn.co.uk** and countries), with a major new search product due from Microsoft soon. Meanwhile, Google is being increasingly criticised by some users (including the writer) for delivering unfocussed portal-based results that cause the user to search all over again on a portal site (e.g. a search for "hotels Dorset" would result in hotel directory web sites being listed).

Yahoo, now a decade old, is waiting in the wings to take over the top spot from Google, but it lacks the clean minimal front-end that Googlers value so much. Meantime it's also worth trying other engines including **www.teoma.com** or **www.dogpile.com** to see if they make life easier when searching the Internet.

What's in An (IP) Address?

This month's *Net Work* column looks at domain names – starting with some background on domains and those mysterious things called IP addresses. Domain names such as **wimborne.co.uk** are nothing more than human-recognisable address labels that represent locations on a network. These locations have unique numerical codes called IP – Internet Protocol – addresses such as the IP of 62.64.162.72, which is the unique IP address that my system was allocated when it connected to the Internet a few seconds ago. Web servers, mail servers and domain name servers (DNS) have unique addresses that identify them on the Internet. At **www.internic.net** there is a non-technical document explaining DNS in more detail.

It's the job of the domain name system to translate friendly human-readable addresses into the unique numerical address that networks can understand. In a nutshell, when you type a web site address (URL) into your web browser, your Internet Service Provider refers to a domain name server that translates your request into the unique IP address related to that domain. Once the numerical code has been "resolved" then you're in business: your ISP can connect you to the server that hosts the web site related to the domain. If there is no web server configured for that domain (or if e.g. the domain is non-existent), you'll get an error message.

When you email **fred@epemag.wimborne.co.uk**, the DNS resolves the friendly readable address into the IP address of that domain. The domain configuration also contains mail routing information (the mail exchange or MX records), and it's the job of the email recipient's own ISP to route mail through their network to his mailbox.

One problem for Internet service providers has been that there haven't always been enough IP addresses to go around. It is critical that mail and web servers have a fixed (static IP) address, otherwise the Internet wouldn't know where to take you when you typed **www.epemag.wimborne.co.uk**, or if you sent an email to fred. But when you connect to the Internet, it isn't always necessary for you to have the same IP address every time. Instead, your presence may be allocated an IP from a pool of numbers – a *dynamic* IP address – which is returned to the pool ready for use by someone else after you disconnect. Demon Internet (**www.demon.net**) was unusual in allocating a static IP to its dialup customers from day one, and the writer's original **epemag.demon.co.uk** address still has the same IP some ten years later. The latest upgrade to the IP system (IPv6) allows for considerable growth in numbers.

A fixed address is fundamental for those who run their own servers (mail or web) or who use virtual private networking (VPN) to connect from home to their office network. Static IP is also handy for videoconferencing, so that you always know the IP address of other users (which you can "dial" through your webcam program). If you want to know your own IP address when online, visit a site such as **www.ipchicken.com** or type **winipcfg** at the Run line. In Windows XP, right-click the dial-up icon in the System Tray, click "Status" and then click the "Details" tab to see your IP address.

Your IP is Your Fingerprint

Thanks to your IP address, whenever you connect to the Internet you leave fingerprints everywhere. The ISPs know the phone numbers being used to connect to the Internet, due to the use of Caller Line ID. They also register IP addresses allocated to Internet sessions. When you access almost any web site, logs on the web server record the IP address of the user (but **not** their name, email address or any personal data – logs only understand IP addresses). Thus a web server record is created of the fact that (say) IP address 62.64.162.72 downloaded files called **project index.html** and **myproject.jpg** on whatever time and date the requests were made.

By analysing web server and ISP logs, experts can compile data about which IP address downloaded what and when, and if necessary they can trace the route all the way back to a telephone number and therefore to a physical address. A number of hackers who tried to penetrate secure systems had their IP traced and were captured red-handed, even though they were hacking into computers in another country altogether.

It is also common for web site owners to analyse web server logs to glean general statistics about usage and bandwidth. On a sister magazine, the writer regularly trawls server logs to track down unusual patterns of activity. A massive download from the same IP might point to, say, a third party web site enframing our web pages within their web site, in breach of our copyright, or linking to our graphics and using them in their own web pages. It is routine to find examples of unwanted linking or suspicious downloading and put a stop to it.

Logs can also tell us what web browsers and what operating systems are being used by visitors (48% of you have Windows XP, less than 1% use a Mac or Linux, one of you runs CP/M and one of you has an Amiga!). Logs indicate what search engine terms were typed in to arrive at our web site, the volume of traffic sorted by hour, day, week and month. Raw server logs can be analysed in very many ways to determine click-through patterns and a whole lot more besides. If logs aren't available, there are many third-party statistic services that web site owners can use instead, such as Extreme Tracking (**www.extreme-dm.com**) or FreeStats at **http://freestats.com**.

Broadband Turn-On

Broadband continues to roll out across Britain, with satellite users signing up with suppliers such as **ehotspot.co.uk**. Other vendors such as WRBB (Wireless Rural Broadband) promised much but have slipped away into the night. Britain's dialup users can however cheer to news from BT that broadband trigger levels have been shelved.

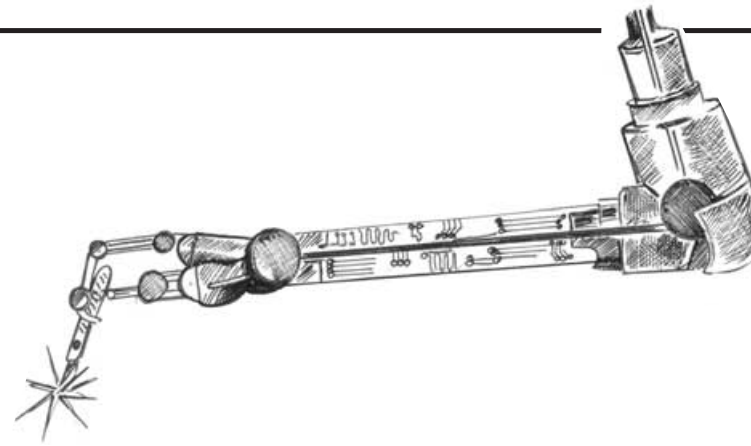
Most phone exchanges will be ADSL-enabled by 2005, and there is encouraging news on rate-adaptive ADSL that allows the distance between user and 'phone exchange to be increased as well. Their web site (**www.bt.com**) quotes a conversion date for the author's exchange (yippee!) of 25th May 2005.

This is an about-turn following their unloved "thermometer" trigger level system (see *Net Work* September 2002) which showed how frustratingly remote the prospects of receiving ADSL appeared to be. BT now promises alternative technologies in areas where ADSL will never be available.

Next month I'll continue with practical aspects of domain names: how to find one, buy one and utilise it. You can email comments to **alan@epemag.demon.co.uk**.

Regular Clinic

Circuit Surgery



Alan Winstanley and Ian Bell

We look at H-bridge inverter MOSFET protection, and some characteristics of light-emitting diodes this month.

Back E.M.F. Protection

"I'm experimenting with an inverter to generate alternating voltages from a pulse width modulation controlled current into a primary coil of a transformer. I believe that a common method is to use a centre-tapped primary with the supply voltage at the centre tap. By alternately switching each primary ground, the alternating e.m.f. is induced into the secondary.

"However, I wish to use only a single primary, with direction of current controlled by an H-bridge type of arrangement. With the first set up, protecting the MOSFET switches would be a matter of shunting each coil to the centre tap with a diode, each diode with its cathode connected to the centre tap. This way, the diodes block the passage of current from the centre tap to ground when the relevant switch is open, but allow the back e.m.f. to be dissipated around the coil when the switch snaps shut.

"How would I protect against back-e.m.f.s in a second set up though: a diode would work in one direction but would effectively short the system in the other. I was thinking about using two back to back Zener diodes across the primary but I don't know what the proper solution is." Thanks from ***Gerard Galvin*** by email.

When current in an inductive load such as a motor or transformer secondary is switched off the magnetic field, which had been established by the supplied current, collapses inducing a reverse voltage known as the back-e.m.f (electromotive force). This back-e.m.f. may result in voltages large enough to damage or destroy the semiconductor devices used to switch the load.

The more rapid the change in current as the inductor is switched off, and the larger the inductor value, the greater the back-e.m.f generated. A 12V relay coil, for example, can generate over 300V reverse voltage when the coil switches off.

The usual method of preventing the back-e.m.f. from causing problems is to place a diode (sometimes called the "freewheeling diode") across the inductor. This diode is reverse biased when the power device is on, but is forward biased by the back-e.m.f. so the diode dissipates the power or feeds it back to the power supply. Obviously the freewheeling diode must have sufficient switching speed, and power handling capacity, to cope with the energy from the back-e.m.f.

H-Bridge

An outline of a typical H-bridge driver circuit is shown in Fig.1. The pairs of diagonally opposite transistors (TR1/TR4 and TR2/TR3) are alternately switched on together by the drive circuit causing the current to alternately flow in opposite directions through the load. All transistors should be briefly off during the switchover to prevent the series transistors from causing a short circuit of the supply.

As our reader points out, the fact that current is switched through the load in both directions in an H-bridge means that we cannot put protection diodes across the inductor. The standard arrangement for protection diodes for a MOSFET H-bridge is given in Fig.1. The diodes (D1 to D4) are reverse biased with respect to normal circuit voltages during all parts of the switching cycle, but are forward biased with respect to back-e.m.f.s and therefore provide a path for the current to feed back into the power supply, and they clamp (or limit) the voltage across the transistors.

Many power MOSFETS include internal protection diodes so you may not have to add extra diodes to your circuit. However, the internal diodes (if present) are not necessarily adequate in all situations so it essential to consult the device's data sheet. Adding external diodes as shown is a sensible precaution. *I.M.B.*

Overrated L.E.D.s

"I have read that if you operate a white l.e.d. at its rated capacity (say 20mA) that heating occurs in the l.e.d. chip and that its life is reduced dramatically. Pulsing it at 10% to 20% on-time and at a higher voltage will reduce the power consumption, extend the life and yet yield the same apparent light output.

Also, is there a quantitative way to measure the intensity of an l.e.d. for comparative purposes? One suggestion is to measure intensity at one metre distance from a white wall. I would welcome your comments." ***Bill Merson,*** by email.

There is a lot of interest in power l.e.d. applications, which are finding their way into torches, security illuminators and decorative lighting. My favourite source of information about the operation of light-emitting diodes is Agilent (a company that evolved out of HP's optical components division), see **www.agilent.com**. Some extremely interesting data sheets are available from their web site, which will appeal to more advanced constructors and design engineers alike.

In Agilent's Application Note I-005 *Operational Considerations for LED*

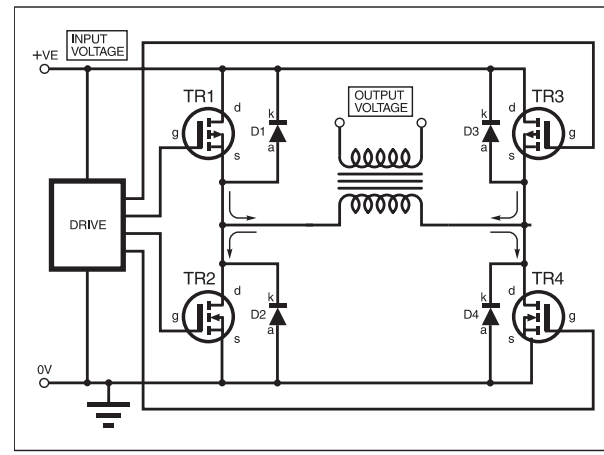


Fig.1. Outline H-bridge circuit showing MOSFET protection diodes, and direction of current flow.

lamps and Display Devices, it is stated that for best pulsed operation, a rectangular current waveform of 100Hz or more is strongly recommended. In this mode it is the *peak* junction temperature, not the average that determines the performance of the l.e.d., says Agilent.

Stressed Out

The same data sheet provides fully worked examples of calculations for both pulsed and d.c. l.e.d. operation, bearing in mind the heatsinking requirements necessary to ensure the l.e.d. chip is not operated beyond the maximum allowed. It is the l.e.d. chip temperature which ultimately determines precisely how far you can "push" an l.e.d.

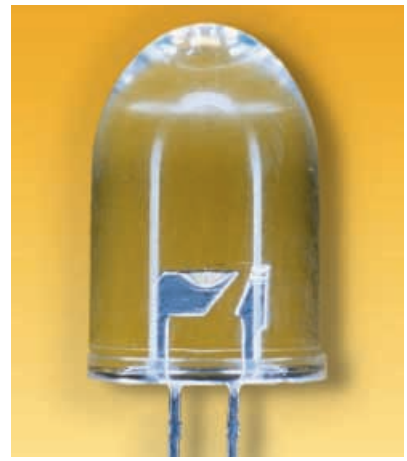
Like every other semiconductor device, the permissible power dissipation is a function of the forward current multiplied by the forward voltage, as well as factoring in the ambient and junction temperatures and the effects of thermal resistances (these last values indicate how quickly the l.e.d. chip can pump heat away to ambient before the chip overheats).

In fact, you can overdrive an l.e.d. beyond the published ratings provided that you are mindful of temperatures, which is probably the biggest single factor determining lamp reliability. Pulsing an l.e.d. may induce thermal stress in the l.e.d. assembly, notably the internal gold wire connector, and reduce reliability. Heat is also generated when the chip is turned on and this would contribute to failure in high power uses.

I am often surprised by the lack of copper track heatsinking on high-power l.e.d. projects. Heatsinking can be provided in the form of copper track areas on the printed circuit board, to sink heat away from the anode or cathode as necessary. Which electrode needs to be heatsinked depends on the l.e.d. design, but usually you would aim to heatsink the cathode (easy to identify by looking into the package: the Cup "reflector" containing the l.e.d. chip is usually the cathode.)

Pulsed or D.C. Operation?

Agilent states that d.c. operation is better than pulsed operation when considering light level output. They say that it is better to drive an l.e.d. with a high d.c. current to obtain the necessary light output to be viewed by a human observer. A high peak current and low duty cycle to pulse-drive an l.e.d. produces less average light output over time.



A large superbright l.e.d. – the cathode is the "cup" terminal, on the left and the gold connecting wire can also be seen.



Standard red l.e.d. with tinned steel wire leadouts. The flat on the body denotes the cathode. Photos: Alan Winstanley

They go on to say that there are only two reasons for wanting to pulse drive an l.e.d. anyway: to strobe an array of light-emitting diodes (e.g. in moving message displays), or to obtain a peak pulse of light to be received by a detector in a non-visual emitter/ detector application, when a peak pulse of light produces a high peak photocurrent in the detector. We might want to pulse an l.e.d. in order to save power: indeed the first l.e.d. pocket calculators (the l.c.d. had yet to be invented), used digital l.e.d. displays that were multiplexed, or flashed on and off in sequence too fast for the human eye to notice, in order to help with battery life and reduce the number of connecting wires needed.

More information on the heatsinking requirements of l.e.d.s is given in Agilent's Application Brief A04 *L.E.D. Lamp Thermal Properties* and also Application Brief I-002 *Thermal Resistance Values for L.E.D.* lamps. We have also touched upon l.e.d. heatsinking in *Circuit Surgery*, November 2002.

Intense Light

On the second question about light intensity, I think it would need a specially calibrated rig to measure l.e.d. output characteristics in any meaningful way. Measuring against a white wall would not be effective, because there are too many variables including ambient light and varying colour temperature (e.g. sunlight or incandescent bulbs), making it impossible to produce consistently accurate and meaningful readings. A standardised and calibrated optodetector would be needed, operating under controlled conditions.

Measuring intensity is one thing, but how to measure colour? In order to describe colours, a standard colour model called the CIE (Commission International d'Eclairage) was created in 1931 and has been adopted internationally. Its use goes beyond the scope of *Circuit Surgery* but one excellent reference is at **www.colorsystem.com/projekte/engl/37ciee.htm**. For hobby use though, it's never necessary to characterise or classify l.e.d.s to such an extent. You will find much more information on using l.e.d.s in our new *Light Emitting Diodes* series starting in this issue. *A.R.W.*



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12	Assorted 7-segment Displays	£1.00	30	Asstd. dil sockets up to 40 way	£1.00
35	Assorted l.e.d.s, var. shapes, colours & sizes	£1.00	10	TV coax plugs, plastic	£1.00
25	5mm l.e.d.s, red or green or yellow	£1.00	40	metres very thin connecting wire, red	£1.00
25	3mm l.e.d.s, red or green or yellow	£1.00	20	1in. glass reed switches	£1.00
75	5mm l.e.d.s, green, 6-5mm legs	£1.00	100	Any one value ¼W 5% cf resistors range 1R to 10M	£0.45
50	Axial l.e.d.s, 2mcd red Diode Package	£1.00	10	7812 Voltage Regulators	£1.00
25	Asstd. High Brightness l.e.d.s, var cols	£1.00	300	Asstd. resistors, ¼W/½W, mostly on tapes	£1.00
20	BC182L Transistors	£1.00			
25	BC212L Transistors	£1.00			
30	BC237 Transistors	£1.00			
20	BC327 Transistors	£1.00			
30	BC328 Transistors	£1.00			
30	BC547 Transistors	£1.00			
20	BC547B Transistor	£1.00			
30	BC548 Transistors	£1.00			
30	BC549 Transistors	£1.00			
25	BC557 Transistors	£1.00			
30	BC558 Transistors	£1.00			
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Constructional Project

EPE Wart Zapper

Thomas Scarborough



Exterminate those unwanted warts with this low-cost easy-build project – high success rate reported in "field tests"

AS IMPROBABLE as it may seem, the common wart may be destroyed with a simple circuit that uses a tiny keyfob battery delivering a boosted 24V to the skin. Taking into account the resistance of the skin, this translates to just 100μA or so passing through the wart internally, thus delivering a fraction (about one-quarter) of the peak power delivered by a typical TENS unit.

Removing warts has never been much fun, and the use of the EPE Wart Zapper is likely to be painful – but only briefly, and not too much.

Burn-Out

The present method is far to be preferred over the messy and painful practice of burning off warts with liquid nitrogen (also called cryosurgery, or "controlled frostbite")! Besides, liquid nitrogen treatment may be counter-productive, in that it sometimes augments the treated warts, it sometimes does permanent damage to the skin (particularly darker skin), and poses a far greater risk of infection.

A more modern method of removing warts goes by the name "electrodesiccation" (or sometimes, "radio frequency thermal ablation") – that is, burning off warts electrically with several *watts* of power. This is tidy, and is *quicker* than the method presented here. However, electrodesiccation tends to be expensive, and is unavailable to people in less developed or more remote areas of the world. Also, it could be dangerous to try to implement as an amateur project.

The EPE Wart Zapper therefore brings the destruction of warts within the scope of the amateur constructor. For the price of a doctor's consultation for the dreaded liquid nitrogen treatment, or for the price of a single session of electrodesiccation, several Zappers could be built. Moreover, it should destroy many warts with a single keyfob battery.

Origination

The Wart Zapper originally came about by accident. The author suffered a local infection which eluded antibiotics, and decided to treat it with Crane frequencies. Without knowing what voltage or current to apply, the treatment was surprisingly and entirely successful – yet it caused some damage to the skin. *What if*, he thought, Dr. Crane's frequencies would cause similar damage to *warts*?

Four successive prototypes were tested on several volunteers, as well as two prototypes being tested by doctors. The final prototype achieved close to a 100% success rate with the common wart (a brown or skin-coloured, rough wart), and significant success with other types of wart.



Before and after sequence.

The Zapper's high success rate does not of course guarantee that it will work in every case. However, it does offer reason for hope that the device would be effective in a great many cases.

Five theories have been put forward as to why the device works:

1. It disrupts the normal functioning of cell membranes through cell resonance
2. It destroys the chemical composition of cells through electrolysis
3. It causes ionotophoresis (the leaching of ions into the wart)
4. It stimulates immunomodulatory chemicals
5. Ionic agitation within the wart results in frictional heating, causing tissue coagulation.

How It Works

The present project was deliberately designed on the basis of No.1 – namely the disruption of the normal functioning of cell membranes through cell resonance. The theory is that alien cells, such as wart cells, begin to resonate when bombarded with a specific electrical frequency. This disrupts the normal chemical processes at the cell boundary, and kills the cell.

However, in practice, the Zapper worked better than this. In many cases it appeared to explode the wart cells, and this could on occasion even be heard.

Theory No.2 (electrolysis, or a "flat" d.c. voltage) was also found to have a significant effect on warts – however, this did immediate, superficial damage to healthy tissues as well, and the experiment was not repeated. Thus it is thought that electrolysis may *contribute* to the destruction of warts, but it does not seem to offer an adequate explanation as to why the present circuit works.

Of the other possibilities listed earlier, No.3 (iontophoresis) would seem to be excluded, since probes made of various metals, as well as graphite, were tried with equal success.

SAFETY AND CAUTION

Despite the very small currents used by this circuit, little is understood about the effects of electricity on the human body, and the EPE Wart Zapper *should be used with this caution in mind.*

In early experiments, when the author was seeking to establish the correct "exposure" required to destroy a wart, he caused himself some temporary damage to a nearby fingernail. Similarly, an article in EPE *("Electrotherapy – A Brief History", Dec '03) reported stiffness in a finger joint that had been subjected to a related treatment.*

These are relatively minor side-effects, yet it should be borne in mind that the Zapper is capable of doing some damage if misused. Therefore the voltage, current, frequency, and duration of treatment described in this article ***must not*** *be rashly modified. A year's experimentation lies behind this design, and most if not all of the mistakes have hopefully been made.*

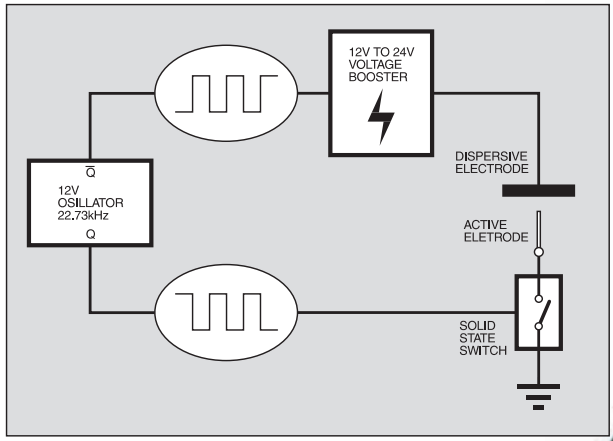
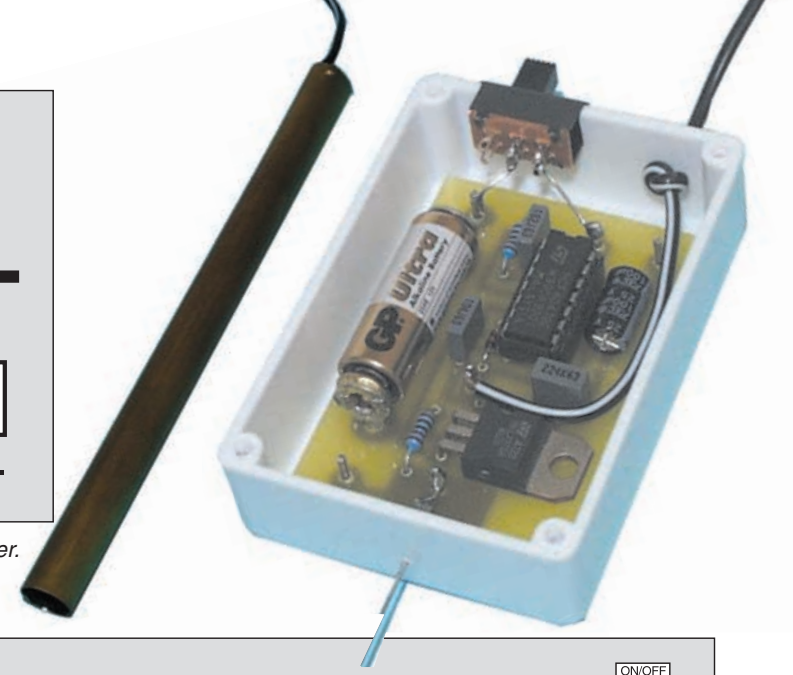


Fig.1. Simple block diagram for the EPE Wart Zapper.



Theory No.4. (the stimulation of immunomodulatory chemicals) would seem hard to explain in light of the spectacular destruction of some warts.

Finally, while the author had no way of testing No.5 (frictional heating through ionic agitation), it would seem unlikely that a few milliwatts of power would raise the temperature within a wart to the 47°C required for its complete destruction – that is, for the denaturation of tissue proteins.

Medical History

During the 1950s, Dr. John Crane established a frequency close to the one used in the present design, as one ideally suited to treating warts and the wart virus (strictly speaking, a group of viruses), and this is used here with suitable voltage and current.

While researching this project, the author found two Crane frequencies for warts (2·127kHz and 21·27kHz), and empirically settled on the higher frequency.

It has since been questioned whether Dr. Crane's frequencies are at all significant, or whether *any* frequencies within a few hundred or even thousand Hertz would work just as well. Assuming that Dr. Crane's 21·27kHz frequency is indeed optimal, close frequencies and harmonics might yield similar results. A frequency close to Dr. Crane's original frequency is followed here, with the important difference that it is applied directly to a wart, rather than being used as a treatment for the virus.

Practical Experience

Although, during testing, virtually all common warts and plane warts were ultimately removed by the Wart Zapper, there were some differences in the effect that the device had.

In several cases, a wart was obliterated first time, never to return. These were usually small common warts, less than 4mm in diameter. However, with close constellations of warts (at first glance looking like a single wart), or with larger warts, the wart was sometimes destroyed in part, but needed follow-up treatments (or simultaneous treatments) to destroy all of it.

During testing, only one wart proved to be really difficult to remove, and in this case it measured 12mm across. After four simultaneous treatments, it had been significantly reduced in size (to almost half), but was still some way from complete destruction. It would be worth commenting that this particular wart completely defied liquid nitrogen treatment.

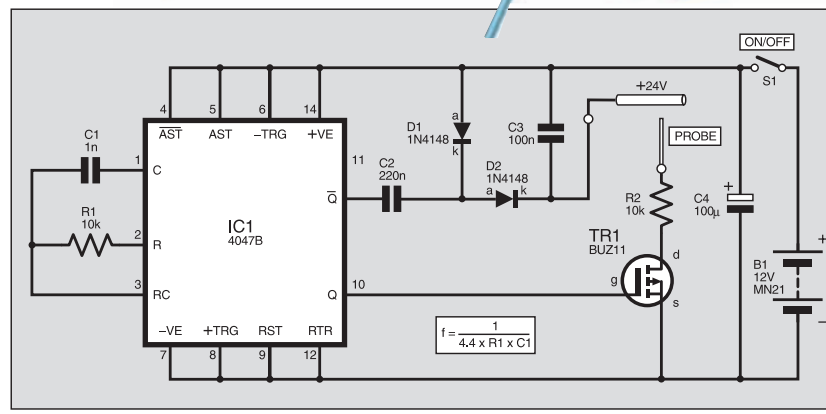


Fig.2. Complete circuit diagram for the EPE Wart Zapper.

In almost every case, little or no pain was experienced when the Zapper was first applied, although one subject jumped when the device was first switched on (this may be obviated with a small modification – see "Circuit Refinements" later).

After a certain period of painlessness, which varied from about half a minute to three-and-a-half minutes, subjects suddenly felt a burning or even "spine-chilling" pain, inside and under the wart. This pain only lasts about half a minute, and then it subsides. However, it is necessary for the removal of the wart, and needs to be "stuck out". When the pain has subsided (or after five minutes, whichever may come first), the probe is removed.

It should immediately be apparent that the wart is "just not the same" – in fact in many cases, the wart melted with a fizzle even before the treatment was over. The skin immediately surrounding the wart may be irritated for a few hours, and there may be a slight swelling around the wart.

Ultimately a scab is likely to form, and perhaps three weeks after treatment the wart should "give up the ghost" and come off – or, in some cases, partly come off. Don't ever remove a wart too soon, or break its surface, or even agitate it, since this could leave a deep wound, and infection could represent a risk. If it is left alone, there should be no infection.

If a treatment should have little or no effect, it would be sensible to consult a doctor.

Circuit Description

The EPE Wart Zapper uses a single oscillator i.c. (see block diagram Fig.1) with two complementary outputs. The author used the $\overline{Q}$ output to power a 12V to 24V voltage booster, and the Q output to switch a solid-state switch (a power MOSFET), to pulse 24V through the electrodes.

One of these electrodes is positive (+24V – called the *dispersive* electrode), and this may either be a metal grip held in the hand, or a metal plate applied to an area of skin near a wart. The other electrode is negative (0V – called the *active* electrode), and this is a sharp(ish) metal point, which is used for direct contact with the wart.

After much experimentation, the author settled on a 24V 22·73kHz (to accommodate standard component values) square wave, applied to a wart for five minutes. It was found that pulses of a minimum 1mW power passing through the wart internally were required to achieve any effect, and that 3mW to 6mW pulses were adequate.

The full circuit diagram for the EPE Wart Zapper is shown in Fig.2, and very little is required for the circuit to work effectively. Theoretically, it simply needs to pulse 24V at a little more than 21kHz, using a square wave of equal mark-space ratio. Current across the probes is limited by resistor R2 to 2·4mA maximum, so as to protect the circuit if the probes should be short-circuited.

One needs also to factor in the conductivity of the flesh, and this rarely falls

below about 200k, therefore little more than about 100μA would course through the wart itself.

The oscillator (IC1) is a CMOS 4047B i.c., which offers superior performance to most simple *CR* oscillators. This includes an internal divider, which guarantees an equal mark-space ratio for the square wave. The frequency of the square wave at pins 10 and 11 is roughly calculated by the formula $f=1/(4{\cdot}4 \times R1 \times C1)$. A doubled frequency (45·45kHz) is available at pin 13.

Transistor TR1 provides an efficient switch, for pulsing the voltage through the flesh, and may be almost any power MOSFET. The voltage at TR1's gate is shown in Fig.3. C4 serves as a supply decoupling capacitor, and S1 as an on-off switch.

The miniature 12V keyfob battery used in the prototype (an MN21 or 23A) would be expected to last about 10 hours to 20 hours continuous, depending on the make of the battery.

Construction

The EPE Wart Zapper is built on a printed circuit board (p.c.b.) measuring just 60mm x 40mm (2½in. × 1½in.). The topside component layout, off-board wiring details and full-size copper foil master are shown in Fig.4. This board is available from the *EPE PCB Service*, code 464.

As will be seen from the photographs, the prototype is built into a very small case. It should not be difficult, in fact, to redesign it to fit into an oversized "pen".

Commence construction by soldering the battery holder to the p.c.b. (two 8mm crimp terminals), attaching a round-head (No.2) paper fastener to the negative (0V) crimp terminal. Solder the seven solder pins and the 14-pin dual-in-line (d.i.l.) socket to the p.c.b., take note of it's orientation.

Mount and solder in position the two resistors, the four capacitors (note the orientation of C4), the two diodes, and transistor TR1 (also note these orientations).

Two solder pins stand spare on the p.c.b., in case a different battery and/or active electrode should be used.

Assembly

Insert the p.c.b. in the case as shown in the photographs. Mount on-off switch S1

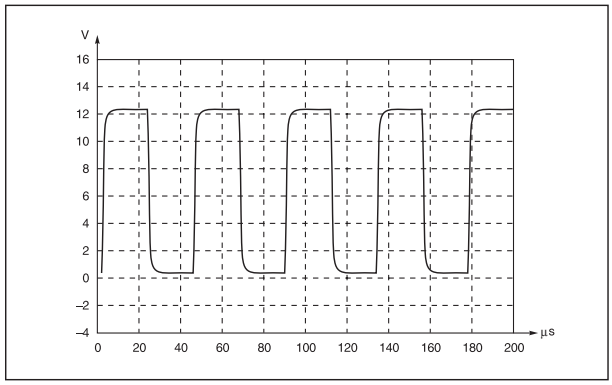


Fig.3. Waveform showing the voltage at MOSFET TR1's gate.

Circuit Refinements

The author decided on a bare-bones approach to the design, and various refinements may be added as desired.

For instance, an ultrabright l.e.d. with a 10k ballast resistor in series may be wired between IC1 pins 11 and 7, as a simple indication that the unit is on and working. This would, however, increase current consumption (and reduce battery life) by as much as one-third. Also, an audible sign of life may be added to the circuit when in use, or even a "battery low" indicator.

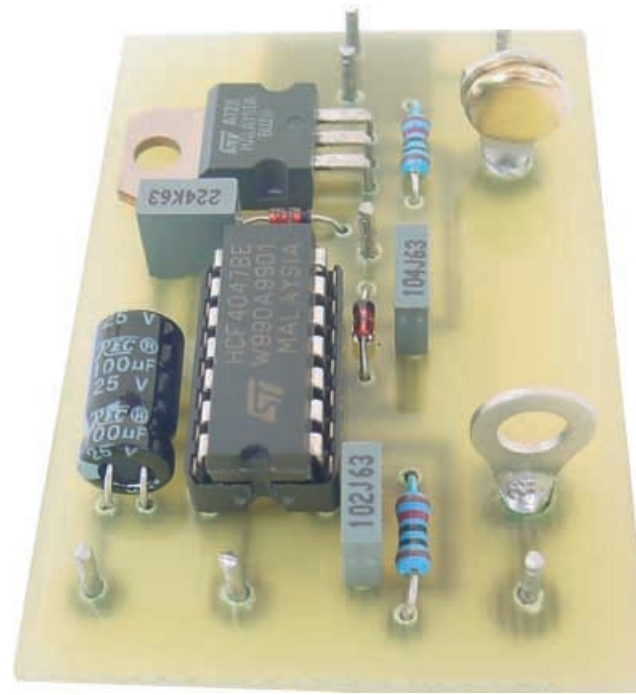
For all but the brave, it is recommended that a 470k potentiometer be inserted into the dispersive (+24V) electrode's wire to prevent the possibility of a brief electrical jolt at switch-on, or on first applying the active electrode to a wart. In this case, the unit is switched on and the active electrode applied – then the potentiometer is turned up (that is, its resistance is reduced).

Boost Voltage

Lastly, it might be worth explaining how and why the circuit comes to pulse 24V through a wart when its battery is only rated 12V.

Most importantly, the higher voltage helps the circuit to overcome skin resistance, so that it is able to provide the 3mW to 6mW power necessary to destroy a wart internally. As the voltage is raised, so the power pulsed through the wart increases, as is confirmed by the equation $I = V/R$.

This boosted voltage is achieved by means of a standard voltage doubler, which is powered by the spare $\overline{Q}$ output pin 11 of IC1. A 12V battery thus directly powers the circuit, while a boosted 24V is switched through MOSFET TR1 to the electrodes.



Layout of components on the completed p.c.b. showing the battery "terminals".

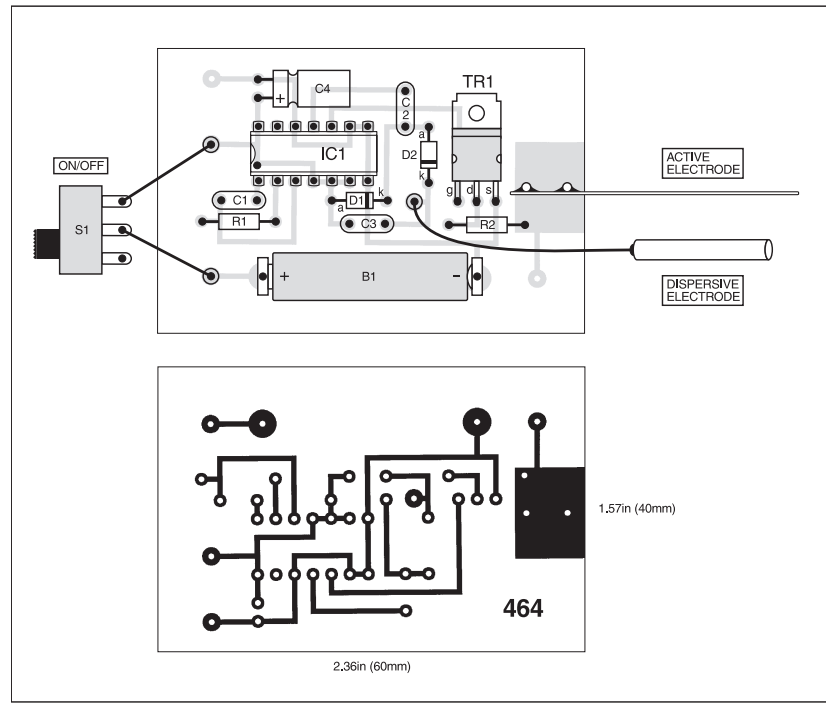


Fig.4. Wart Zapper topside printed circuit board component layout and off-board wiring details together with a full-size underside copper foil master.

on the case, and connect it as shown (this should be switched off to begin with). Be sure to insert the battery the correct way round in its holder, since the circuit has no reversed polarity protection – a mistake here could destroy the circuit.

Drill a hole in the case next to the switch, through which the wire to the dispersive electrode (a metal grip or metal plate) is passed, and solder it to the dispersive electrode solder pin as shown. Make sure that there is sound electrical contact to the metal grip or plate.

Now drill a hole for the active electrode, which is inserted through the end of the case, and soldered to the two solder pins as shown. This probe may be a needle which has had its sharp point filed off with a fine file to make a sharp(ish) stub.

Insert IC1 in the d.i.l. socket, observing anti-static precautions (first touch your body to ground). The whole p.c.b., if desired, may be secured in the case with a little epoxy glue.

In Use

Considerable experimentation preceded the development of this circuit, and the results gave the author a new respect for the potential risks of electricity, however small the voltages and currents which are applied.

Skin resistance can vary between about 100k (kilohms) and 8M (megohms), depending on the day and the situation. Therefore to ensure consistency of results, skin resistance needs to be kept relatively low. Use a little skin moisturiser where the skin makes contact with the dispersive electrode, as well as a little moisturiser on the wart itself.

Constructors are advised not to use the circuit where current would flow across the head or the heart, and *never* in a case where a person uses a pacemaker or has any history of epilepsy. All the precautions that apply to a TENS device apply also to the Wart Zapper.

Treatment

If treating a wart e.g. on the lower or upper arm, hold a metal grip (the dispersive electrode) in the same hand. If it is not convenient to use a grip, rest the limb to be treated (e.g. a foot) on a metal plate instead, which is again connected as the dispersive electrode. The active electrode, which is a sharp metal point (but not too sharp) – is rested directly and gently on the top of the wart – see Fig.5.

If the wart is large (say 5mm or more in diameter), it might be an idea to tackle one or the other side of it first, since the Zapper is unlikely to kill all of it at once.

Switch on, apply the Wart Zapper to a wart for up to five minutes (see above), then switch off. Be prepared for the possibility of a brief initial jolt, and be prepared to suddenly experience perhaps half a minute of sharp pain. If you do not see this through until the pain subsides, the wart may not be destroyed.

The Wart Zapper came as a welcome relief to the author's son, who could not bear the suggestion of further treatment with liquid nitrogen. He claimed that it was far preferable, and that the pain was "not bad" in comparison. When asked after school one day how his treated warts were progressing, he replied, "Very badly – for the warts!"

No Guarantees

While this circuit comes with no guarantees, it is nothing ventured, nothing gained! The author, with several willing "guinea-pigs", and further volunteers queuing up, found that the EPE Wart Zapper was entirely successful – most of the time. □

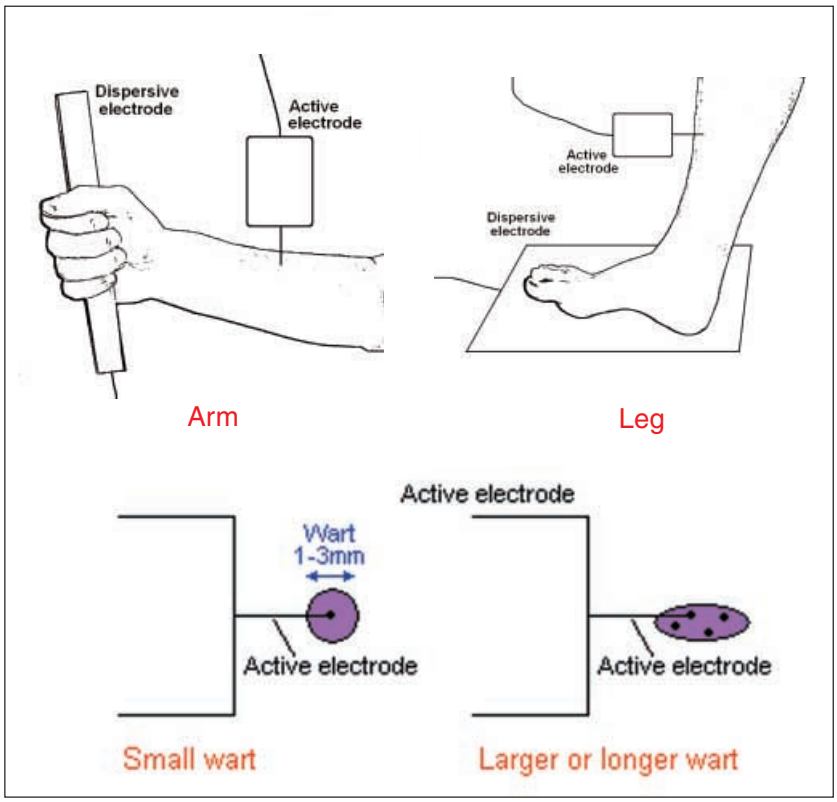
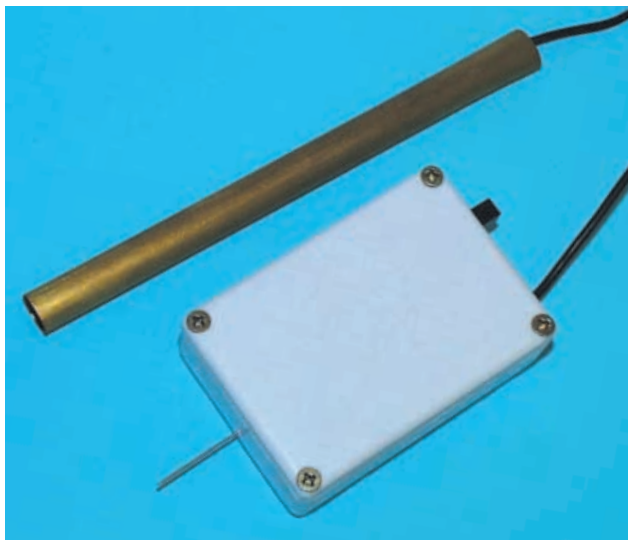


Fig.5. Suggested wart treatment procedures.



COMPONENTS

Resistors

R1, R2	10k 0·25W 5% carbon film (2 off)

See SHOP TALK page

Potentiometer

VR1	470k/500k miniature rotary carbon, lin. (optional – see text)

Capacitors

C1	1n polyester
C2	220n polyester
C3	100n polyester
C4	100μ radial elect. 16V

Semiconductors

D1, D2	1N4148 signal diode (2 off)
TR1	BUZ11 *n*-channel power MOSFET (or similar, e.g. IRF510)
IC1	4047B CMOS oscillator

Miscellaneous

S1	on-off slide switch
B1	12V MN21/A23 keyfob battery

Printed circuit board (60mm x 40mm) available from the *EPE PCB Service*, code 464; small ABS case, size 70mm x 50mm x 25mm approx.; 14-pin d.i.l. socket; brass pipe (140mm x 10mm dia.) for dispersive electrode; 40mm needle for active electrode; roundhead (No.2) paper fastener and 8mm crimp terminal (2 off) for battery holder – see text; 1 metre insulation multistrand connecting wire; solder pins (7 off); solder etc.

Approx. Cost Guidance Only **£8** ***excl. batt.***

Constructional Project

AlphaMouse Game



John Becker

Let that mouse sort out those shifty characters!

Do you remember those childhood toys which comprised a square frame enclosing 15 or more letters that you slid around to arrange into different orders? Perhaps even your children have one now. In their day they were the forerunners of Rubic's Cube, before both became ousted by PlayStation and the like.

Recently, the author was considering how best to illustrate in a simple fashion the way in which a PC's mouse could be put to alternative good use with a PIC, following on from his article *PIC to PS/2 Mouse and Keyboard Interfacing* (Aug '04). Somehow, these letter frames came to mind, and sparked off a series of high-speed bashings at the keyboard to write the code for a modern equivalent.

The result of just a few hours coding and programming is this AlphaMouse Game, in which a 2-line 16-characters (per line) alphanumeric liquid crystal display (l.c.d.) replaces the lettered frame, and a PC's PS/2 mouse controls the movements of 31 letters around the 32-position area.

Trappings

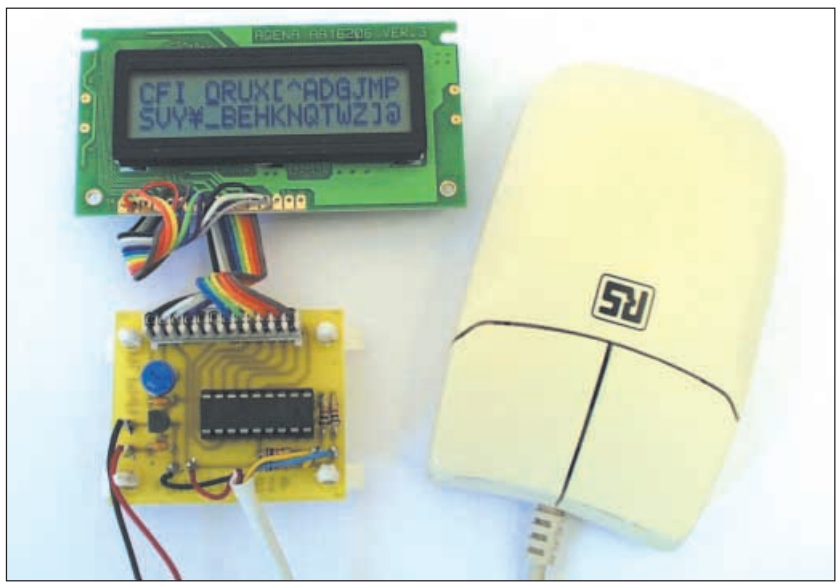
Unable to resist addiction again, the author has inevitably used a PIC microcontroller to do the hard work, interpreting your leisurely efforts at moving and clicking the mouse as the whim takes you. And unlike the original frame game, you've been provided with the full 26-letter alphabet, plus a handful of symbols to arrange into what ever order takes your fancy.

There is a randomiser which selects the letters presented and in what order prior to each game. The variety is practically infinite, and you are probably as likely to get repeats of letters scattered around as you are to get just one of each. Should you find some games looking harder than others, you may even activate the randomiser again if you don't like the offering!

You can also deliberately select games in which four spaces instead of one are provided, into which the letters can be shunted while sorting the others. Even the author, not normally one for much game-playing, found himself getting hooked on the game's fascination – and the way in which it is sometimes necessary to "trap" a letter using others, in order to make it go into the space you want. A bit like persuading sheep to go into their pen without a sheepdog!

All of this fun can be had with just a few components – four resistors, a couple of capacitors, a PIC16F627 (or 628) and an l.c.d. Not even a crystal is needed, nor a voltage regulator if you use a 6V battery. But if you use a regulator the game can be run with a 9V battery. Oh, and you need a PS/2 type mouse – but your PC is likely to have one of those anyway, and even if it doesn't, one can be bought inexpensively from any computer supplier.

Software and pre-programmed PICs for the AlphaMouse Game can be obtained as stated later.



Circuit Description

So, look at Fig.1 – it shows how simple the circuit is. The PIC microcontroller is notated as IC1, to which the mouse is connected at pins RA0 and RA1 via socket SK1. Pin RA0 is used by the software in both input and output modes for data transfer between the PIC and the mouse. Consequently, resistor R3 is in series with the connecting line to buffer it, and R1 is used to bias the pin high when it is acting as an input, as required by the mouse's own controller chip.

As this circuit can also be used with the keyboard interface described in the July issue, it also includes resistors R2 and R4, as required by that software for mutual accessing of the clock pin (RA1) by the keyboard and PIC. For this mouse game though, R2 can be omitted and R4 replaced by a wire link (but it does not matter if both these resistors are retained).

The PIC controls the l.c.d., X1, in 4-bit mode via Port B. The pins here are used in the author's standard order. Preset potentiometer VR1 controls the l.c.d.'s screen contrast, and once set can be ignored.

For those who wish to power the game from a 9V battery (e.g. PP3), voltage regulator IC2 should be included, to drop the supply down to +5V. For those who want to power the game using a 6V battery (using four AA type cells, for example), IC2 should be omitted, but linking its allocated input and output pads on the printed circuit board (p.c.b.).

Power line smoothing capacitors C1 and C2 should be retained whichever power source you use. Switch S1 is optional.

That's all there is to it! Indeed it will be spotted by those who use the author's *Toolkit TK3* PIC programming hardware and software, that the circuit can be readily assembled on *TK3*'s board, and the game played from there!

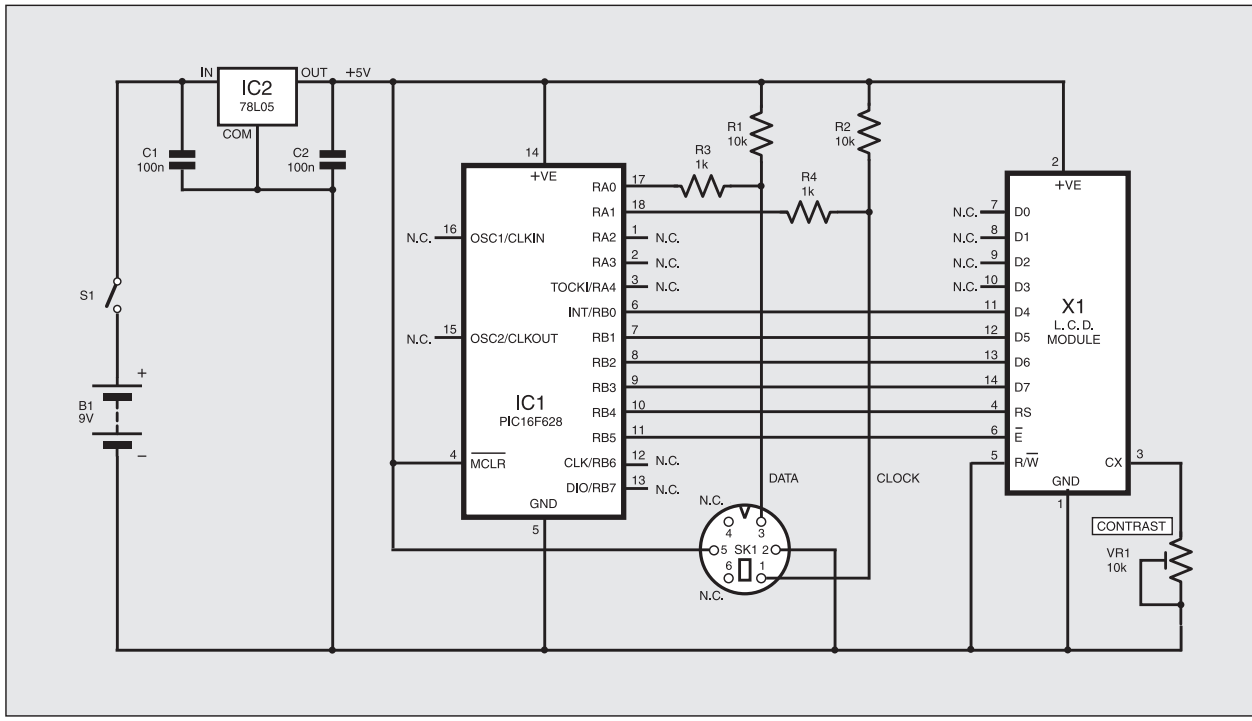


Fig.1. Complete circuit diagram for the AlphaMouse Game.

Construction

Despite the last comment, a p.c.b. has been designed for use with this game. It is available from the *EPE PCB Service*, code 466. Its assembly and track layout details are shown in Fig.2.

You should, of course, use a dual-in-line (d.i.l.) socket for the PIC. Start off assembly by inserting the socket (but without the PIC at this stage!). Then solder in the other few components in ascending order of size. After which, add 1mm terminal pins for the l.c.d., power supply and mouse. A standard mini 6-pin female DIN connector should be connected to the latter via short leads. The pinouts are shown in Fig.2.

As always, check everything before applying power (we don't want you exclaiming anything in unusual letter sequence having damaged something through carelessness)!

It's up to you as to whether you box this game as a permanent source of future entertainment. If you do, a plastic one measuring 150mm × 80mm × 50mm would do the job nicely, once you've cut an l.c.d.

COMPONENTS

Approx. Cost Guidance Only **£13** *excl. battery*

See SHOP TALK page

Resistors

R1, R2	10k (see text)
R3, R4	1k (see text)

Potentiometer

VR1	10k min. round preset

Capacitors

C1, C2	100n ceramic disc, 5mm pitch (2 off)

Semiconductors

IC1	PIC16F627 or PIC16F628 microcontroller (pre-programmed) (see text)
IC2	78L05 +5V 100mA voltage regulator (optional – see text)

Miscellaneous

S1	min. s.p.s.t. switch (optional)
SK1	mini 6-pin DIN female connector, line or chassis mounting to suit
X1	2-line 16-characters (per line) alphanumeric l.c.d. module

Printed circuit board (optional – see text), available from the *EPE PCB Service*, code 466; 18-pin d.i.l. socket; battery and connector to suit (see text); 1mm terminal pins; connecting wire; solder etc.

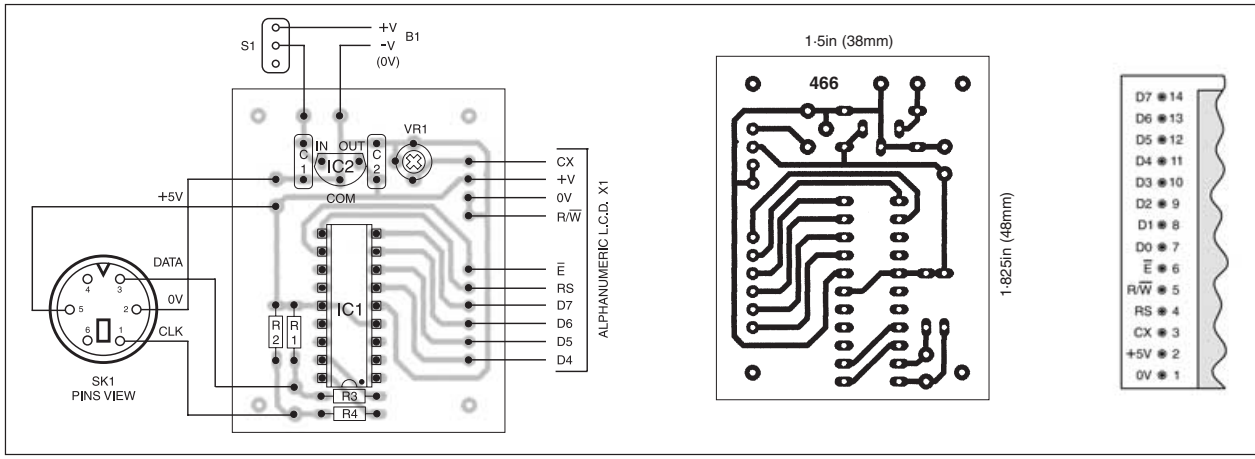


Fig.2. Component layout and master track pattern for the AlphaMouse Game. Typical l.c.d. pinouts are shown to the right.

viewing slot, of course. You would also need the power on-off switch S1 (without a case you can just plug a battery in and out of a connector).

It just remains for you to discharge static electricity from your body, by touching something earthed, then carefully push in the pre-programmed PIC (the right way round), apply power – and the game is on!

Random Beginnings

When power is applied, the PIC sets up the l.c.d. for use in 4-bit mode, it then enters the randomisation routine. At power-up time the PIC's registers take on random values and one of these is taken as the initial "seed" for this routine.

There are 32 registers allocated to hold the letters or other characters that will be displayed on screen. A 32-step loop is entered in which the "seed" value is added to a counter.

Each time round the loop, that counter's value is ANDed in the W register with 31 to restrict its range. Then 64 is added to convert that value to one within the l.c.d.'s character generator range between 64 and 95 (from the @ symbol, through the 26 capital letters A to Z, followed by "[", an unprintable (by our typesetting system) oriental symbol, then "]", "^" and "_". The character symbol value is stored into the letters register pointed to by the loop count.

Because the "seed" value is never zero (intentionally avoided), the counter's value changes each time round the loop, and so different characters are selected at each step, 32 of them.

At the end of the loop, the next random value is used to determine where the blank space is to be placed. The whole lot is then displayed on the l.c.d. screen, such as:



Game Play

In case you don't know, the idea of the game is to rearrange the random set of characters into any order that suits you. For example, from "A" upwards, or "Z" downwards, with the additional symbols in whatever order you choose. There are no rules – it's up to you.

The only way in which you can rearrange the characters is in the painstaking way! First you have to move the mouse vertically between the two lines and sideways along them until the underline (cursor) symbol appears below the character you want to move. That character, though, must be adjacent to the blank position on screen, to the left or right, above or below the blank.

Left-clicking the mouse on the chosen character will cause it and the blank to change places. You then choose and click the next letter to move. More often than not while arranging the sequence you will in effect simply be moving the blank in order to capture the next character of the sequence. If you don't have patience, this game is not for you – there are no shortcuts (unless you rewrite the program)!



Having arranged the letters in the required sequence, you have won! (Off to the hospitality zone for suitable refreshment!) But the bug's probably hit you – so play again . . .

Well, you could try to rearrange the sequence in the opposite order, as you probably did with the original frame game. Or you can activate the randomiser again. There are two ways of doing this with your mouse, either click both buttons simultaneously, or click the right one (the left one on its own has no effect on accessing the randomiser).

Clicking either of these button options runs the randomiser in the same way as when power was first applied. However, the "seed" acquisition is different. While you were challenging nature's natural ordering system and imposing your own, another counter was running at the same time. It is the much rolled-over 8-bit value that this has acquired which now becomes the "seed"; and the next time you select randomising, another "seed" will have grown, and so on.

It's worth noting (as you probably will) that some sequences appear more random than others. This is usually due to whether the "seed" has an even or odd value. Odd values will normally generate greater variety. But you have no control over this – if you dislike the sequence you see, click again to select another.

If both buttons are pressed, at the end of the 32-step randomising loop, just a single blank is generated. However, if you hold down the right hand button slightly longer than the left, four blank spaces will be scattered on screen at random. This might make the game a bit simpler (but don't count on it!). You do not even need to use the left button if you want to give yourself four blankety-blanks, just click the right button.

While randomising is going on (and repeats the sequence over and over for as long as buttons are pressed), the screen flashes each sequence at speed. You really do see your letters being well-sorted (and without postcodes too)!



Sheepdogging

While in the four-blanks game, you will often have to "shepherd" the chosen character into the required blank slot, whereas it actually wants to go into another adjacent slot (a mind of their own, these letters, sometimes).

But you, by knowing the rules of shepherding, can countermand such woolly behaviour:

The program has been written so that it checks whether a clicked character does indeed have an adjacent blank slot. The order checking for blanks is:

1. Check for blank to the left of character. If present accept it.
2. If not present, check for blank to the right of character. If present accept it.
3. If not present, check for blank above character (if selected line has an "above"). If present accept it.
4. If not present, check for blank below character (if selected line has a "below"). If present accept it.
5. If not present, you've selected a letter without an adjacent blank, so try again with better self-control!

Suppose now you have selected a letter to move, and it has more than one adjacent blank – could even have three. You want the character to go into the blank above it, but in accordance with the above rules of engagement, the wretched sheep (sorry – *character*) wants to go left, and is determined to do so!

You're the bright one – stop that escapee's route so that it has to go up into capture. Bring in a letter from the left to get the left blank out of the way. But now the protocol dictates the escape route is to the right, so you need to block that too. Surrender and capture! Other similar situations are not uncommon – all the more fun to the hunting order!

Pic 'N Play

So there you are, a simple but entertaining novelty for you to put together. It also shows one application for using a PIC with a PS/2 mouse. There are countless more to be invented. If you're a PIC programmer, invent some!

It would also be fun for any PICer to play around with the simple code for this AlphaMouse and add other features to it. It would also be worthwhile reading the *PIC to PS/2 Mouse and Keyboard* article referred to earlier.

Resources

Software, including source code files, for the AlphaMouse Game is available on 3·5inch disk from the Editorial office (a small handling charge applies – see the *EPE PCB Service* page). It can also be downloaded *free* from the *EPE* Downloads page, accessible via the home page at **www.epemag.wimborne.co.uk**. It is held in the PICs folder, under AlphaMouse. Download all the files within that folder.

This month's *Shop Talk* provides information about obtaining pre-programmed PICs, and the sourcing of components.

The PIC program source code (ASM) was written using *Toolkit TK3* software (also available via the Downloads page) and a variant of the TASM dialect. It may be translated to MPASM via *TK3* if preferred.

The run-time assembly is supplied as an MPASM HEX file, which has configurations embedded in it (internal oscillator, WDT off, POR on, all other values off). If you wish to program the PIC yourself, simply load this HEX file into the PIC using your own PIC programming software and hardware. □

Next Month

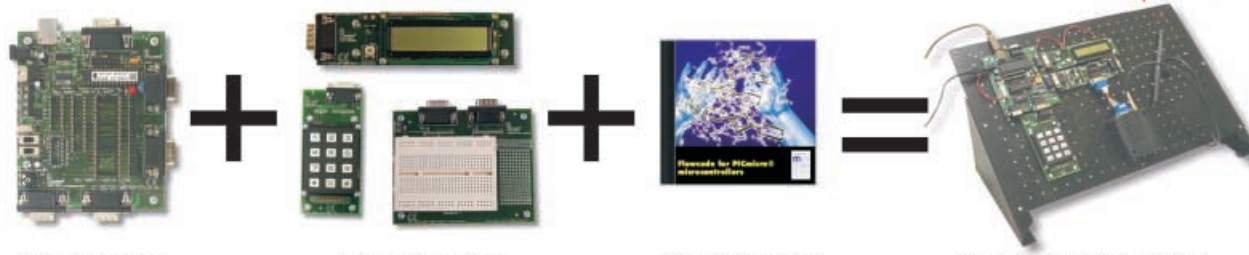
To conclude our look at interfacing PICs to mice and keyboards, next month we show a moon and tide clock design which has its settings adjusted by a PS/2 keyboard.

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651.593	600W Continuous	24V	£101.59	£83.76
651.587	1000W Continuous	12V	£177.18	£147.52
651.597	1000W Continuous	24V	£177.18	£147.52
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PRACTICALLY SPEAKING

Robert Penfold looks at the Techniques of Actually Doing It!

OBTAINING all the components for a project, right down to the last nut and bolt, can be frustrating and time consuming. It might be possible to get all the components from one supplier, but many projects now seem to require at least one special component that is not widely stocked. You just have to accept that it will sometimes be necessary to order parts from two or three suppliers, especially when building larger projects.

The Truth is in There

Many projects now require one or two components that are difficult to track down. Fortunately, in the case of *EPE* projects at least one source will have been located for you by the author or the staff. Details of suppliers for "awkward" components will often be given in the text of the article or in the components list.

Also refer to the magazine's *Shoptalk* feature, which gives buying advice for every project featured that month. A lot of your time and ours can be saved by checking the magazine properly for the information you require before making an enquiry. The answer is almost certain to be in there somewhere.

Many component suppliers now have online catalogues and ordering systems, but it is still worthwhile obtaining printed versions of a few component catalogues. You can learn a great deal about components by browsing through catalogues. Identifying the real thing is much easier if you have familiarised yourself with the components by studying the photographs in catalogues first.

When building old designs it is important to check that all the components are available before you start buying any of them. It is an irony of modern electronics that the chances of obtaining an electronic valve from 60 years ago are often better than those of obtaining a semiconductor produced just a few years ago.

There were big changes in the world of electronics during the 1990s, and this rendered many popular projects of the past obsolete. A few recent devices have popped up only to disappear again shortly afterwards. It is sensible to ascertain the availability of all the components before starting to buy the parts for any project.

Stock Answers

Life is much easier if you have a stock of the more frequently used components. To some extent this is a matter of convenience, and it avoids having to order long lists of components each time you wish to construct a project. It is only necessary to order the more specialised items if you already have the "run of the mill" components. Buying small components such as resistors and capacitors one by one tends to be quite expensive, so buying a stock of them is potentially cheaper in the long run.

A good stock of components is definitely an asset, but "good" is the important word here. Unless the components are chosen wisely you will waste a lot of money buying a "pig in a poke". There is no point in buying components for stock unless you are likely to use them in a reasonable time span.

In general, it is not worthwhile having expensive components in stock. To do so would tie up a significant amount of money, and there would be no guarantee that the components would ever be used. Try to concentrate on inexpensive components that feature regularly in most projects.

The humble resistor is the obvious starting point, but do not bother with the more exotic types such as close tolerance (one or two per cent) and high power components. These are used infrequently, and are relatively expensive. Ordinary 0·25 watt 5 per cent tolerance carbon film resistors are a different proposition, since they feature prominently in practically every project and are quite cheap. The only complication is that a large number of different values are used, but with careful buying it should be possible to obtain several hundred resistors for a few pounds.

It is definitely worth considering one of the resistor packs that are offered by some component retailers. These typically offer a full range of values from 10 ohms to one megohm, or possibly an even wider range.

The contents of these packs are usually weighted to take into account the fact that some resistor values are used more than others. Values of 1k, 4k7, 10k, 47k, and 100k for example, tend to be used far more than most other values. Very high and very low values are used relatively little.

Experience suggests that the weighting in favour of the more popular values is inadequate, and these still tend to be used up first. However, the weighting should ensure that you do not end up with stacks of little-used values. If you do a large amount of project construction it will probably be worthwhile buying 100 of each of the most popular values.

Doubling Up

In the early days of what was then *Everyday Electronics*, readers were sometimes advised to build up a stock by buying twice as many resistors as they actually needed, and this remains a good way of doing things. Clearly this method does not provide an instant stock of resistors, but it is relatively painless because you will hardly notice the increased cost of each project. The clever bit is that you will automatically obtain larger quantities of the popular values, and less of the little-used ones. Furthermore, the weighting should accurately reflect the true popularity of each value. A stock can be built up more quickly by ordering three of four times as many of each value than are actually needed for each project.

Another way of obtaining a stock of resistors is to buy "bargain" packs of surplus stock. While these packs offer good value for money, they do have potential drawbacks. In particular, the range of values included could be quite small, and there is little chance of a full range being covered. The included values might not be ones that you use very often, and there could be some unusual values.

Most projects for the home constructor only use resistor values in the E12 series (1, 1·2, 1·5, 1·8, 2·2, 2·7, 3·3, 3·9, 4·7, 5·6, 6·8, 8·2 and their decades). It is probably only worth stocking resistors in this series of values.

Resistors are also available in the E24 series, which consists of the E12 series plus 12 intermediate values (1·1, 1·3, 1·6, 2·0, 2·4, 3·0, 3·6, 4·3, 5·1, 6·2, 7·5, 9·1 and their decades). As these values are little used in projects for the home constructor it is best to buy them only when they are needed.

Bargain packs often include some non-standard values, and you might also find that many of the resistors are old and (or) high wattage components. These are often too big to fit into modern component layouts. Bargain packs are better suited to "old hands" who can quickly sort through the components, spot the useful ones, and then test them.

Preset resistors (potentiometers) are not as cheap as ordinary resistors, but a small stock of them should not cost too much. Again, obtaining a pack having a full range of values is likely to be much cheaper than buying the components individually. Ordinary potentiometers are relatively expensive, and it is probably best to buy them as and when they are needed.

Capacitors

Building up a useful stock of capacitors is difficult due to the huge range that is currently available. Each value is available in several types, and within each type there could well be several physical variations. Buying a really comprehensive stock of capacitors would therefore be extremely expensive. Unfortunately, capacitors cost a little more than the "dirt cheap" prices associated with resistors. Being realistic about it, when building up a stock of capacitors it is necessary to make compromises.

It is probably best to start with the higher value capacitors, which are normally of the electrolytic variety. Physically, there are two general types of electrolytic capacitor. These are the axial lead and radial (printed circuit or p.c.b.) mounting varieties.

The axial versions seem to be little used these days and most modern projects require the radial type. A radial component will usually fit quite well in place of an axial type, so you can probably manage quite well without any axial electrolytic capacitors.

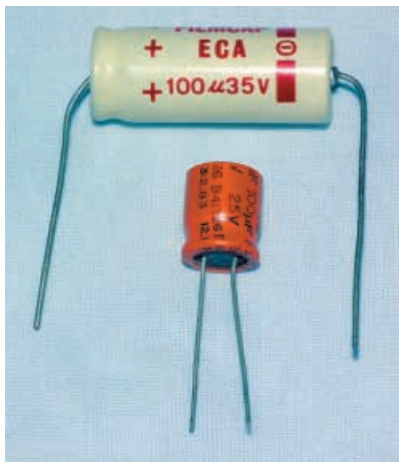


Fig.1. The 100µ 35V axial electrolytic dwarfs the more modern 100µ 25V radial type below

High value capacitors are only widely available in the E6 range of values, which is just every other value in the E12 series (1·0, 1·5, 2·2, 3·3, 4·7, 6·8 and their decades). However, only every other value in this series (1·0, 2·2, 4·7 and their decades) is used to any extent. A basic stock of electrolytic capacitors could, therefore, be rationalised to something like 20 each of the following values and working voltages.

1µ	50 to 100V	10µ	50V	100µ	16V
2µ2	50 to 100V	22µ	25V	220µ	16V
4µ7	50 to 100V	47µ	25V	470µ	16V

It's a Matter of Values

Very high values tend to be used less than the lower values, so 10 of each value above 10µF would probably suffice. The very high value components are quite expensive and it is not worth stocking them on the off-chance that you will need them one day.

Buying bargain packs of electrolytic capacitors is risky because these components are not noted for their longevity, and older components are often massive when compared to modern equivalents (see Fig.1). Packs of new electrolytic capacitors are a much safer alternative.

Middle value capacitors of about 1nF to 470nF in value are available in such a wide range of shapes and sizes that it is impractical to stock them all. Probably the most popular types these days are the printed circuit mounting (box-shaped) type with 5mm (0·2 inch) or 7·5mm (0·3 inch) lead spacing. A small stock of either or both of these would be useful, as would some 100n ceramic capacitors.

Values of less than 1nF are relatively little used these days, but are available in several types such as ceramic plate, polystyrene, and silvered mica. Ceramic plate capacitors are the cheapest and are consequently more widely used than the other types. This makes them the best choice for stock purposes, but they are unlikely to be good substitutes for other types.

Semiconductors

The range of semiconductors on offer to electronics hobbyists is truly vast. Many semiconductors are specialised components but there are some "standards" that are worth having in stock.

The NE555 timer is possibly the most used chip in designs for the home constructor. Although perhaps not as popular as it was in the past, it is still worthwhile having a few of the standard chip and a low-power version such as the TLC555CP. Beginners can have a lot of fun and learn a great deal by experimenting with some 555 timer projects.

A vast range of logic devices is available, with several variations on each basic type. The rise of the PIC processor heralded the decline of ordinary logic devices, so it is probably not worthwhile stocking any of them. The once standard 741C op.amp (operational amplifier) is also little used these days and has been superseded by various improved but different versions.

The TL071CP is a good choice for a stock op.amp, as it has a generally high specification and works well at low voltages, but it will not replace all other op.amps. It should only be used in designs where it is stated that a general-purpose op.amp is all that is required.

No constructor should be without some general-purpose silicon diodes such as the 1N914 or 1N4148. These can often be bought in quantities of 50 or 100 at quite low prices. Some small rectifier diodes such as the 1N4007 are also useful. Note that this component can be used safely in place of lower voltage versions such as the 1N4002 and 1N4004.

It is worth having some small transistors, but bear in mind that substituting semiconductors is a bit risky unless you know what you are doing. If an article states that any general purpose transistor will do, then either a BC549 (*npn*) or BC559 (*pnp*) should be fine. Even if two transistors have the same encapsulation they will not necessarily have the same leadout configuration, so due care *must* be taken in order to avoid connection errors. Some larger component catalogues have leadout diagrams and there is no shortage of semiconductor data on the Internet.

Nuts and Bolts

It is definitely a good idea to have a stock of small mechanical items such as nuts, bolts, and spacers, which are easily forgotten when ordering the parts for a project. The most reliable means of mounting circuit boards is to use bolts about 12·5mm to 25mm long. 6BA bolts used to be the best choice for this application, but these days either the slightly larger M3 or smaller M2·5 metric types have to be used.

Experience suggests that M2.5 bolts are best for mounting stripboard, and the M3 size is best for custom printed circuit boards. Some matching spacers about 5mm or so in length are normally used to hold the board clear of the case. Plastic stand-offs offer an alternative means of mounting boards, but few of them seem work well with stripboard.

Beginners should start with *battery* powered projects, so it is a good idea to have some PP3 size battery connectors. Other useful mechanical parts to have in stock are some small control knobs and d.i.l. (dual in-line) holders for 8-pin, 14-pin and 16-pin integrated circuits.

Make sure that you also have plenty of insulated connecting wire such as 7/0·2 equipment wire, and a large reel of 22s.w.g. multi-core solder. This avoids the frustration of running out of one or the other just as a project nears completion.

Compartmentalise

With even a modest stock of components it is important to have everything stored sensibly so that any desired component can be quickly found.

It is easy to improvise a storage system, but it is not necessarily worthwhile as the real thing can now be obtained quite cheaply from DIY stores, etc. These units are probably intended for woodscrews and the like, but most of them are perfect for electronic components.

Small compartmentalised trays and boxes are also ideal for storing electronic bits and pieces (see Fig.2). In general, lots of small compartments are better than a few large ones. You can then have a limited range of values in each compartment, making it easy to find the right one.



Fig.2. Small compartmentalised trays make it easy to quickly find the required component. This one contains dozens of p.c.b. mounting capacitors.

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DID YOU MISS THESE?

MAY '03

PROJECTS ● Super Motion Sensor ● Earth Resistivity Logger – Part 2 ● Door Chime ● Back-To-Basics–4 (Live Wire Detector, Medium Wave Radio). **FEATURES** ● Ingenuity Unlimited ● Techno Talk ● Practically Speaking ● Circuit Surgery ● Net Work – The Internet Page ● *SPECIAL SUPPLEMENT* – EPE PIC Tutorial V2 – Part 2.

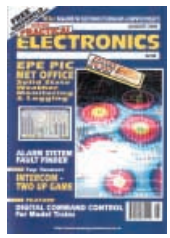
JUNE '03

PROJECTS ● Fido Pedometer ● PICronos L.E.D. Wall Clock–Part 1 ● Back-To-Basics–5 (Mini Theremin, Twilight Switch) ● Radio Circuits–1 (Crystal Set, MK484 TRF Receiver, Headphone Amplifier). **FEATURES** ● Ingenuity Unlimited ● Techno Talk ● Interface ● Circuit Surgery ● New Technology Update ● Net Work – The Internet Page ● *SPECIAL SUPPLEMENT* – EPE PIC Tutorial V2 – Part 3.

JULY '03

PROJECTS ● EPE Mini Metal Detector ● Low Range Ohmmeter Adaptor Mk2 ● Radio Circuits–2 (Q-Multiplier, MW Reflex Radio, Speaker Amplifier) ● Ultimate Egg Timer ● PICronos L.E.D. Wall Clock – Part 2. **FEATURES** ● Ingenuity Unlimited ● Circuit Surgery ● Techno Talk ● Practically Speaking ● Flowlog Lite Review ● Net Work–The Internet Page.





AUG '03

PROJECTS ● EPE PIC Met Office–1 ● Alarm System Fault Finder ● Master/Slave Intercom ● Electronic Two-Up ● Radio Circuits–3 (Regenerative Receivers). **FEATURES** ● Digital Command Control for Model Trains ● Ingenuity Unlimited ● Circuit Surgery ● Interface ● Techno Talk ● New Technology Update Net Work – The Internet Page.

SEPT '03

PROJECTS ● PIC-A-Colour ● Vibration Alarm ● Priority Referee ● EPE PIC Met Office–2 ● Radio Circuits–4 (Tuning Systems). **FEATURES** ● Using the PIC's "High" Operator ● Practically Speaking ● Ingenuity Unlimited ● Techno Talk ● Circuit Surgery ● Net Work – The Internet Page.

OCT '03

PROJECTS ● RC Car Wars ● Serial Interface for PICs and VB6 ● Practical Radio Circuits–5 (Super Regen. Receiver) ● Spooky Bug. **FEATURES** ● PIC Breakpoint ● Ingenuity Unlimited ● Interface ● Techno-Talk ● New Technology Update ● Net Work – The Internet Page.

NOV '03

PROJECTS ● PIC Random L.E.D. Flasher ● Cardboard Clock ● Practical Radio Circuits–6 (S.S.B. and Direct Conversion Receiver) ● Anyone At Home? **FEATURES** ● Teach-In 2004 – Part 1 ● Ingenuity Unlimited ● Practically Speaking ● Techno Talk ● Circuit Surgery ● New Technology Update ● Net Work – The Internet Page.

DEC '03

PROJECTS ● PIC Nim Machine ● Practical Radio Circuits–7 (Superhet Tuner) ● PIC Virus Zapper Mk2 ● Christmas Cheeks. **FEATURES** ● Teach-In 2004 – Part 2 ● Electrotherapy ● Circuit Surgery ● Ingenuity Unlimited ● Techno Talk ● High-Speed Decimal To Binary For PICs ● Interface ● Network – The Internet.





JAN '04

PROJECTS ● Car Computer ● Practical Radio Circuits–8 (Dual-Conversion SW Receiver) ● Bedside Nightlight ● PIC Watering Timer. **FEATURES** ● GPS to PIC and PC Interface ● Practically Speaking ● Teach-In 2004 – Part 3 ● Ingenuity Unlimited ● Techno Talk ● Circuit Surgery ● New Technology Update ● Net Work – The Internet Page.

FEB '04

PROJECTS ● PIC LCF Meter ● Sonic Ice Warning ● Jazzy Necklace ● PIC Tug-of-War. **FEATURES** ● Surface Mount Devices ● Circuit Surgery ● Teach-In 2004 – Part 4 ● Interface ● Ingenuity Unlimited ● Techno Talk ● Net Work – The Internet Page.

MAR '04

PROJECTS ● Bat-Band Convertor ● Emergency Stand-by Light ● MIDI Health Check ● PIC Mixer for RC Planes. **FEATURES** ● Teach-In 2004 – Part 5 ● New Scientist CD-Rom Review ● Circuit Surgery ● Techno Talk ● Ingenuity Unlimited ● Practically Speaking ● Net Work – The Internet Page.

APRIL '04

PROJECTS ● EPE Experimental Seismograph Logger 1 ● Infra-Guard Monitor ● Loft Light Alarm ● PIC Moon Clock. **FEATURES** ● USB To PIC Interface ● Ingenuity Unlimited ● Teach-In 2004 Part 6 ● Interface ● Techno Talk ● Circuit Surgery ● New Technology Update ● Net Work – The Internet Page ● Pull-Out – Semiconductor Classification Data.

MAY '04

PROJECTS ● Beat Balance Metal Detector ● In-Car Laptop PSU ● Low-Frequency Wien Oscillator ● EPE Experimental Seismograph Logger–2. **FEATURES** ● Coping With Lead-Free Solder ● Teach-In 2004 – Part 7 ● Ingenuity Unlimited ● Techno Talk ● Circuit Surgery ● Practically Speaking ● Pic-N'-Mix ● Net Work – The Internet Page.

JUNE '04

PROJECTS ● PIC Quickstep ● Crafty Cooling ● MIDI Synchronome ● Body Detector Mk2. **FEATURES** ● Clinical Electrotherapy ● Ingenuity Unlimited ● Teach-In 2004 – Part 8 ● Interface ● Circuit Surgery ● Techno Talk ● PIC-N'-Mix ● Net Work – The Internet Page.





JULY '04

PROJECTS ● Portable Mini Alarm ● Bongo Box ● Hard Drive Warbler ● EPE PIC Magnetometry Logger–1. **FEATURES** ● Making Front Panel Overlays ● Practically Speaking ● Teach-In 2004 – Part 9 ● Ingenuity Unlimited ● Circuit Surgery ● Techno Talk ● PIC-N'-Mix ● Net Work – The Internet Page.

AUG '04

PROJECTS ● EPE Scorer ● Keyring L.E.D. Torch ● Simple F.M. Radio ● EPE PIC Magnetometry Logger – 2. **FEATURES** ● PIC To PS/2 Mouse and Keyboard Interfacing ● Techno Talk ● Circuit Surgery ● Teach-In 2004 – Part 10 ● Interface ● Ingenuity Unlimited ● PIC-N'-Mix ● Net Work – The Internet page.

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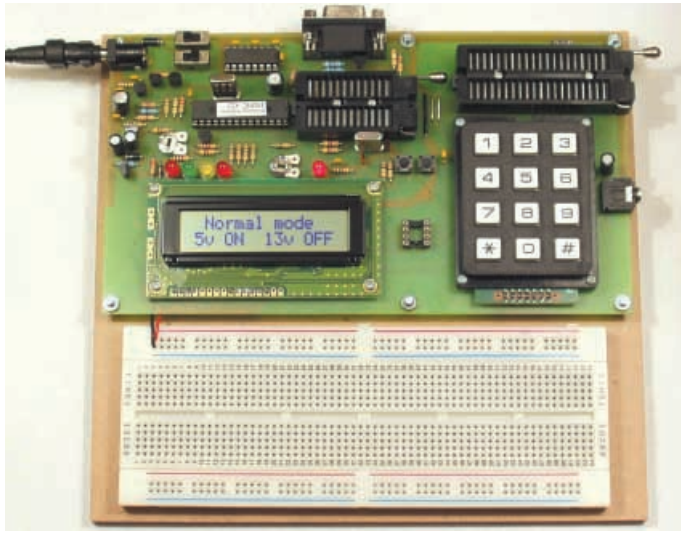
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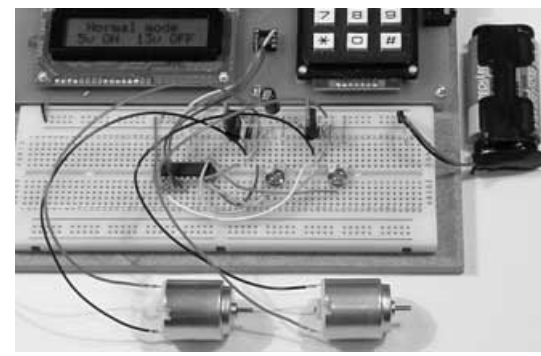
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All letters quoted here have previously been replied to directly.

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★ LETTER OF THE MONTH ★

Overripe Student

Dear EPE,

I am new to electronics, having less than 12 months experience. I suppose I could be called a mature first year student. Although at 70 years of age, *overripe* would be more appropriate.

I am an ex-pat and I've lived "down under" for 32 years. Having emigrated with my wife and kids as part of the last of the £10 tourists on assisted passage. It cost your Government $22.00 to get rid of us. Workaholism kept me in the workforce beyond retirement age, believing that stress won't affect you if you enjoy your work. Two major "heart events" as my wife calls them, soon put paid to that misconception. There was no option other than to retire.

The favoured pastime up until then was flying an ultralight aeroplane. Suddenly grounded and deprived of a favourite pastime, I thought the next best thing would be radio controlled model planes – a "piece of cake". Five scratch-built planes and seven spectacular write-offs later (two belonged to a mate), resulted in another misconception being dispelled. A decision was made to give it up before someone got killed. But I overheard my wife say to our daughter "I daren't think about what he could get up to next".

The problem was solved when I remembered that one of the interesting things about remote controlled model planes is the electronics side of things. So, the decision was made to teach myself electronics. Who would have thought that a mere cerebral pastime could be so challenging and rewarding? I will not pretend that it is easy. There are no courses available to overripe students and learning from books leaves a lot to be desired, especially with my limited IQ. But the advantage of aging is that a drop in testosterone levels allows your brain to grow back a little and helps concentration.

I discovered *EPE* in November 2003 at my local newsagent. Eureka! At last, a publication that lives up to the name "practical", and doesn't assume all its readers are physics or maths graduates. For down to earth, hands on learning, your magazine tops the lot. Your *Teach-In* has been a godsend, and has been more help than all the other publications put together.

Because most of my available time has been spent coming to grips with the theory, only two projects have been completed so far. An adjustable regulated power supply, and the *Bio Feedback Tension Monitor* featured in your Dec '03 issue. The latter has had plenty of use believe me. I can't wait to get started on the *Beat Balance Metal Detector* (May '04). There are plenty of old gold workings not far from here. If I find a record sized nugget I will name it *EPE*!

At the moment BASIC STAMP and other PICs are taking their toll of an aging brain. And even if I never make it to designing my own circuits or devising a new compiler language, it's shaping up to being a lot of fun trying. You can teach an old dog new tricks, you just have to convince him it's worth the effort. So far, thanks to your magazine it's been well worth the effort. It took a lifetime to discover electronics; unfortunately there is not a lifetime to enjoy it. Ah well, "such is life". Thank you for an excellent publication,

Dave Jones,
Brisbane, Australia

As someone "ripening nicely", I hear what you are saying, Dave, although I've not had the mishaps which you've endured (as detailed more fully in your email)! I totally agree about keeping "ze little grey cells" working. The stimulation of electronics, and more particularly software writing, is highly conducive to this!

So thanks for your comments, and best wishes for a productive retirement, helped by EPE*, and that gold nugget!*

IR AutoSwitch

Dear EPE,

I have built Max Horsey's *IR AutoSwitch* (July '02) exactly as it is described in the article and I am experiencing sensitivity problems. In order to trigger the relay, my hand has to be around 10cm away from the sensor while in the text it is stated that this distance is about 30cm. Is there any possible way to increase the sensitivity of this circuit ?

Vassilis Papanikolaou, via email

Max replies:

The physical arrangement of the emitters and sensor makes a large difference to the sensitivity, for example, if some of the infra-red is allowed to reach the sensor by reflections within the case, the sensitivity will be greater. The danger, of course, is that the relay is permanently triggered. Perhaps a better way of increasing the range is to use more efficient IR emitters. A browse through the RS catalogue reveals some new emitters which are worth a try.

Max Horsey, via email

VB Express

Dear EPE,

I have enjoyed your various PIC and Visual Basic projects over the past years (and wanting to see more!). Microsoft plans to release new "entry level" products for their .Net development products, the "Express" series will be available at very little cost (or free). The current beta versions are free to download (**http://lab.msdn. microsoft.com/express/**). I've installed VB 2005 Express, and it even has a serial port "control"! It produces compiled .exe files.

Although the syntax is slightly different from VB6, or the MSCE used in some previous projects, they may be worth a look.

PS: What about a PIC project that transfers data via Bluetooth?

Klaus Lehnert,
Auckland, New Zealand, via email

Thanks Klaus, that's useful info, which I have also sent on to Robert Penfold.

Bluetooth? That may be beyond what we are into at this stage in this context!

Jazzy Kites

Dear EPE,

There will always be the good and the bad, the interesting and not so interesting. I found Thomas Scarborough's *Jazzy Necklace* (Feb '04) interesting. My interest lead me to breadboard the circuit for evaluation. Because I like kite flying at night the circuit had possibilities and I constructed two sets of strings with eight l.e.d.s each, and then fastened each one to the wings of my kite. The control box containing the circuit and battery was in the centre. By using white l.e.d.s the display gave a very distinctive twinkling light.

I've just got back from Kitty Hawk, NC-USA (where the Wright Brothers flew), where I received several great comments as to how nice the display looked. I suppose if I was into PIC's, similar results could have been obtained. Some day I'll get into that. Right now my kite flying activities are taking too much time!

Ray Heller, via email

That sounds great Ray. I sent your comments on to Thomas, who responded:

A really nice letter. This is what I find a lot – that people see more in a project than is published, and I could foresee that the *Jazzy Necklace* might be adapted to other purposes.

Thomas Scarborough,
Cape Town, South Africa, via email

PIC Car Computer

Dear EPE,

Regarding Mike Hibbett's *PIC Car Computer* (Jan '04), the components list quotes three sockets but the circuit diagram shows five. What are the other sockets meant to be, and what is "5-way BERG header"? Also, can I safely replace the 24LC64 with a 24LC256 EEPROM instead?

Gavin Oliver, Australia, via email

Mike Hibbett replies:

Well spotted; SK4 is a header for connecting the batteries, and SK5 is for mounting the keypad. The PCB has 0·1in. pitch holes in these positions, and it is up to you if you wish to fit sockets to mate with the power leads and keypad. No special connectors are required or specified. It will depend on what connection you have on your keypad. The header should be a 4-way, not 5-way. This socket is for the programming interface – if your microcontrol ler is pre-programmed or you use an external programmer, then you will not need to fit a header here. If you are going to fit a 4-way header in SK1, you want a vertical mounting one; these are available from **www.altronics.com.au/cat.asp?cat=14&grp=177&id=P5494**.

In general, any 0·1in. pitch header/connector arrangement may be used. Berg connectors (**www.berg.com**) are widely used, such as on disk drive interfaces, and can be purchased from most electronic suppliers in the UK. Alternatives are Molex connectors which have a friction locking mechanism. I believe that a 24LC256 part can be used in place of the 24LC64, although I have not tested it.

Mike Hibbett, via email

Thanks Mike.

GPS CHECKSUM

Dear EPE,

After experiencing several checksum related problems with the *GPS to PIC and PC Interfacing* project (Jan '04) I thought I would "cry-for-help" and put my problems forward on the Chat Zone. Andrew Jarvis came to the rescue and helped me them sort out.

Here is the code change that solved the first checksum problem, it just requires the extra line indicated:

```
CHECKIT: BLOCK1
      movf INDF,W
      BLOCK0
      xorlw '*'
      btfsc STATUS,Z
      goto CHECK2
      xorlw '*'                ; add this new line
      xorwf CHECKSUM,F
      incf FSR,F
      movf FSR,W
      xorlw $6F
      btfss STATUS,Z
      goto CHECKIT
      goto EOFPROBLEM
```

The next problem that we encountered was a checksum error message whenever the checksum ended in 9. The solution – both commands "addlw 247" in the original should be changed to "addlw 246":

```
CHECK2:  incf FSR,F
      BLOCK1
      movf INDF,W
      BLOCK0
      movwf PROMVAL
      movlw 48
      subwf PROMVAL,F
      movf PROMVAL,W
      addlw 246                ; changed to 246
                                 from 247
      btfss STATUS,C
      goto CHECKV1
      movlw 7
      subwf PROMVAL,F

CHECKV1: incf FSR,F
      BLOCK1
      movf INDF,W
      BLOCK0
      movwf STORE
      movlw 48
      subwf STORE,F
      movf STORE,W
      addlw 246                ; changed to 246
                                 from 247
      btfss STATUS,C
      goto CHECKV2
      movlw 7
      subwf STORE,F
```

I'm using a Motorola Oncore M12+ which is essentially a "bare-bones" GPS module without an l.c.d., keypad or antenna. The native output from the M12+ is Motorola's own binary data format but it can be switched to provide seven NMEA 0183 data sentences, including GPRMC and GPGGA.

The primary difference between the Garmin 12 and the Motorola M12+ is the length of the data fields in some of the NMEA data sentence. The Motorola M12+ has an additional ".00" (fractions of a second) on the Time of Fix field and an extra digit (4 digits not 3) for the seconds field of the Longitude and Latitude values. The possibility of field length differences between GPS manufacturers was pointed out in original article.

I had a look at the code in the *PIC Magnetometry Logger* (Jul/Aug '04) (MAGGY700.ASM) which contains portions of code re-used from GPS320.ASM. I suspect that it will generate the same problems and that the above fixes should be applied to avoid the same checksum problems as I encountered with GPS320.ASM.

Peter Stolcs, via the Chat Zone

Thanks Pete and Andrew for getting this sorted. Yes, the Maggy code was a direct copy of the GPS section. Both sets of code on our Downloads site have been amended, and renamed to GPS330.ASM and MAGGY710.ASM.

I found Andrew's help useful when writing the GPS article, his knowledge in that field being well in excess of mine.

Thanks for L.C.F. Meter

Dear EPE,

I want to thank you again for the Feb '04 *PIC L.C.F. Meter* project on behalf of myself and several members of an Amateur Radio QRP club here in Columbus, Ohio. As I said in a Chat Zone posting, it was one of the most interesting projects that I've played with in a while and I learned quite a bit, both from my own experimentation and from the input of others in the CZ. I have to admit that I was somewhat surprised to see my postings from the CZ in *Readout* of May '04.

Anyway, there have been several iterations of your meter constructed by our club and every one has functioned flawlessly. I have posted pictures on a web page and I thought you might enjoy seeing the various "flavors" of your meter that our members have built, the URL is **www.touchinglittlelives.org/meter/finished.html**.

Also, I'd like to let you know that all of your efforts are appreciated worldwide. There are currently three *TK3* boards in use full time locally that were built by club members from the information presented in the Nov '01 supplement. Besides your *PIC Tutorial* there is also an online PIC tutorial presented by the NJQRP club. Between the two courses, we are slowly muddling our way through these fascinating little beasts!

There used to be several magazines here in the States similar to *EPE* that offered hands-on learning experience through construction articles. Unfortunately the majority are no longer in publication and I am thankful that *EPE* hasn't joined those ranks. I guess it just shows that quality lasts! And, of course, the "more than reasonable" price for an annual on-line subscription makes *EPE* a very cheap investment in quality learning.

Thanks John for your time and your excellent articles.

Mike Doty, Columbus, USA, via email

Reading your email made my day Mike. Thank you!

That's really nice to know on all counts, including the web site. As threatened, you find yourself being quoted in Readout *again! Despite my natural "English reserve", I'm not averse to having my trumpet blown! All the very best wishes to you and your club, and enjoy your PICing . . .*

Crafty Cooling

Dear EPE,

In the Peltier effect project *Crafty Cooling* (June '04), the fan is to extract air from the box, not blow it in. Why is that? Isn't the flow reversible?

I've just decided to fan-cool the box containing some high-wattage resistors on a project I'm working on. Unfortunately, each component dissipates over 1W and, even though 3W rated, they run hot unless fanned. Now, my fan pushes air into the box, the escape route being holes in the walls next to each set of resistors. I thought that this must cause flow in the required direction. Output air feels cool and the box doesn't get hot. But, is "suck rather than blow" recommended for a good reason?

Incidentally, old computers are also a source of re-usable 12V fans (if you don't mind cleaning the dust off first). Even failed power supplies can still be stripped to rescue the fan, and a finger-guard or similar mounting metalwork often comes as a bonus!

Godfrey Manning,
Edgware, Middx, via email

Terry de Vaux-Balbirnie, author of Crafty Cooling, *replies:*

As a physicist, I would say that "suck" and "blow" are, indeed, the same – it is just a case of reversing the direction of air flow. However, the *pattern* of flow will not be the same. In other words, if the fan were used to "blow" air across heatsink fins and subsequently out of the ventilation holes, it would not follow the same course as if air was "sucked" and flowed from the ventilation holes to the fan.

I felt that air entering ventilation holes would tend to pass across the whole area of the heatsink more effectively than if air was blown from the fan. That is why I chose this method and it worked well in the prototype unit. There was no other good reason. It could be that "blow" would be just as good! For your project, I would try both methods and choose the one that works best. I wish you the best of luck with it!

Terry de Vaux-Balbirnie,
via email

Interfacing to VB

Dear EPE,

I have been reading your Robert Penfold's recent *Interface* articles, regarding "Interfacing Visual Basic with the new Inpout32.DLL" (Oct, Dec '03, Feb '04), as well as John Becker's *GPS to PIC and PC Interfacing* article (Jan '04) with great interest.

The articles discuss the interfacing process using VB6. I've recently purchased the standard version of Microsoft Visual Basic.Net and I'm now wondering whether the tools described in the above articles could be used with VB.Net (standard) to do serial port interfacing. If not, could you suggest a cause of action, which would enable me to do serial port input and output from a VB.Net program?

Pieter van Zyl,
Johannesburg, South Africa

As I don't have VB.Net, I sent Pieter's query on to Robert, who replied:

As far as I can gather, there is no way of importing the BAS file into VB.Net in a fashion that will enable the Inp and Out instructions to be recognised. A bit of delving on the Internet came up with a roundabout solution which is to load the demo program supplied with Inpout32.dll, or any similar VB6 program. VB.Net will then convert this to a VB.Net compatible program. You can then edit the program into your new one, and both the Inp and Out instructions should be recognised. I have not thoroughly tested this method, but it seems to work.

I will see if I can work this into an *Interface* article in a bit more detail, including an "empty" VB.Net program that readers can use as a starting point. As you are no doubt aware, VB.net is not exactly ideal for our purposes. VB5/6 are much better.

Robert Penfold,
via email

Thanks, Robert, that would be most useful.

Free PSUs?

Dear EPE,

Chips get smaller and cheaper, power supplies don't. Try your local computer shop (a proper one that does upgrades) and beg an old PC power supply (e.g. the AT variety). It's probably scrap to them, but with ±5V and ±12V it's a useful source for us – just right for logic including TTL (in its modern forms) and dual-rail capability for op.amps. Upgraded computers need more current and further voltage supplies (such as 3·3V) so these old units are becoming redundant.

Godfrey Manning,
Edgware, Middx, via email

Thanks Godfrey – that's worth highlighting!

PIC N' MIX

ANDREW JARVIS

Our periodic column for your PIC programming enlightenment

Hex Files: The Truth is Out There (if you follow the paper trail)

NEVER might you have expected that we would be writing about Teletype machines in this column, or the punched cards and paper tape they processed! (If you're too young to know what that means, Teletype machines were the terminals for old computers that typically used punched paper tape as a storage medium – and they are rapidly disappearing into text books).

The association with PICs is an incongruous one that emerges when you open the "hex" files – those familiar products of programming activity. Assemblers produce them, projects distribute them and programmers utilise them – so the chances are you will have some lying around, even if their *raison d'étre* needs a little investigation.

Absolutely Fabulous

When *TK3* or other assembler converts your program into absolute machine code the result is stored as a hex file (it's "absolute" because the file contains information about exactly where in device memory the code will be loaded, and it can't be changed unless you assemble the source code again). Programmers like *TK3* or an MPLAB PicStart/PicKit 1 combination take the hex files and use them to program the PIC.

In theory, any PIC programmer should be able to take and use a hex file, which makes them a sort of lowest common denominator in PIC development and enables interoperability between different development tools. I can write a program using the MPLAB IDE, assemble it then use *TK3* to program the PIC with the hex file. It also means that I can pass around much smaller files than the ASM equivalent for a project and I can remove the need for interested parties to be required to build the code.

Non Reversible

The interesting point is that this process is not reversible. It is not possible to take a hex file in isolation and know for which PIC it was produced. The format is completely device independent. Hex files are not unique to PICs, far from it. It just happens to be the preferred format for Microchip and therefore most tools that follow their lead. There are other formats that would work just as well if supported, like the Motorola S-record for example.

It's easy to prove that the hex file format is a generic one, because when you look into the detail of them, there is absolutely nothing contained within to tie it to a PIC – which effectively renders it useless unless you tell the programmer which device you are working with. For *TK3* this means "Select PIC type", for MPLAB you must "Select Device" from the configuration menu.

Paper Trail

The hex file has evolved into a few different flavours now, but the origin of the format can be traced right back to when machine code programmers stored their work on paper tape or those old magnetic tape reels. Such media were not exactly reliable, so a more structured way of storing and retrieving data had to be found that was better than simply dumping the bytes sequentially.

I have to confess that I can't imagine writing code using Teletype machines and paper tape. The nearest I got was a ZX Spectrum and boxful of C90 audio cassettes, but even that separated tape-saved data into structured blocks, with a header that contained type information, file name, length of data block and the address from which it was saved.

The physical data structure chosen for hex files would make the process of saving and restoring machine code altogether more robust for the developer of days gone by. The code was represented using printable ASCII characters so that it could be transferred using character-only communication media and it was split into smaller records containing a start address so that the loader would know where to position it. Records began with a start marker and ended with a rudimentary checksum for the loader to validate.

INHX8M

The most common format today for *EPE* projects is the Intel Hex INHX8M, which retains many of the same characteristics described above. There are two different record types to consider; data and end-of-file. Every data record looks like this:

- Start of record mark
 1 byte – ASCII colon character ":"
- Record length
 1 byte – two hex digits that specify the number of data bytes
- Address
 2 bytes – four hex digits that specify the load address for this part of memory, ordered as high byte first, then low byte. Using two bytes here means that the INHX8M format can only be used with a 16-bit address space (max FFFF).
- Record Type
 1 byte – always "00" for the data record
- Data
 n-bytes – two hex digits for every data byte specified in record length. Ordered high byte first, then low byte.
- Checksum
 1 byte – hex representation of the 2's complement of the sum of all preceding bytes

Taking a section of a hex file from an *EPE* project to illustrate this, the code in Listing 1 is the last part of the hex file distributed as **Maggy700.hex** for the *EPE PIC Magnetometry Logger* (July/Aug '04), but any other would do.

Decoding the first line gives a record length of 10 (16 decimal, remember all numbers are hex) following the start of record marker ":". The load address is "0F70" followed by confirmation that this is a data record "00". The bytes from "45" through to "08" are the 16 data bytes and "5B" is the checksum.

Double Jeopardy

The penultimate line is worth a look, also a data record with only two bytes to load at address "400E". Wait a minute! The *EPE Magnetometry Logger* uses a PIC16F877, which has 8K of user memory extending to "1FFF". In programming mode, it extends further from "2000" to "3FFF", though not all configuration memory space is physically implemented.

But still "400E" seems way out. It turns out that every address in the INHX8M format should contain only one byte, but the problem is that every PIC address uses two bytes to represent the instruction word. So every address in the hex file is twice the PIC address we need, and therefore all addresses in the hex file must be halved to get the real PIC address. If we half "400E" the answer is "2007" which we know is the address of the configuration word.

The end-of-file record is much more straightforward:

- Start of record mark
 1 byte – ASCII colon character ":"
- Record length
 1 byte – always "00" – there are no data bytes to follow
- Address
 2 bytes – always "0000" since this field is not used
- Record Type
 1 byte – Always "01" for the end-of-file record
- Checksum
 1 byte – Always "FF", can be pre-calculated

Since all the fields of this record are constant, we can say that the end-of-file record will always look like this: :00000001FF (as confirmed by the last line of Listing 1).

When *EPE* starts to deal in PIC18Fxxx projects, then the hex file format will need

Listing 1. Extract from *EPE Magnetometry Logger* hex file, showing the last seven records.

```
:100F70004522BA0A3A1EB62FBA013D223C163A085B
:100F80005F204522BA0A3A1EBF2F061EC52F5D27D5
:100F9000A5238C1EC92F1A08473C031DC92F932374
:100FA0006827A6275027F60106306225061AD62F95
:020FB000080037
:02400E00323F3F
:00000001FF
```

to change to INHX32 to support the addressable memory range of the 16-bit core. Luckily, it is almost the same as the 8-bit version but with another record type (extended linear address) to describe the upper 16 bits of the address.

As we have already established, you cannot do anything useful with a hex file until you make some assumptions about the device it was intended for. That is exactly what had to be done with the "400E" example – how could it be known it looked wrong if it was not know, that it was intended for a 16F877? But once you have that information then the gloves are off and the code can easily be "mapped" into the memory of a device by the programmer.

The Key to TK3

The key to this particular map is not the datasheet for the device, helpful as that is, but the programming specification, which is an entirely separate document, because it's arguably relevant only to the very enthusiastic, or those with an interest in creating or understanding a programmer like *TK3*. These documents reveal "special" memory locations that are only accessible in programming mode, in addition to the user program memory. They represent User IDs, EEPROM data memory and the PIC configuration word. Microchip actively encourages device programmers to support this "extra" information that can be embedded into a hex file.

Assuming mid-range PICs, if you find an address within the hex file in the range 0000 to 1FFF, then you can reasonably expect that the code is heading for user program memory (1FFF represents the 8K maximum addressable memory space). If it lies within the range 2000 to 2003 then it's identification information (User ID), 2007 is the address of the configuration word and finally the data EEPROM content starts at 2100 and continues with one data byte per address. Remember that in a hex file these address values will be doubled up.

Most of the programming specification documents contain a nice little reminder near the back that demonstrates just how "strongly" Microchip feel about device programer support for this extra embedded information. The reason for it brings us right back to where we started – that of portability. After all, what would be the point of distributing a hex file if you had to also list your configuration settings and EEPROM content, then program them separately. It would surely be quicker to use paper.

Next Time: As much fun as you can have with a hex file viewer.

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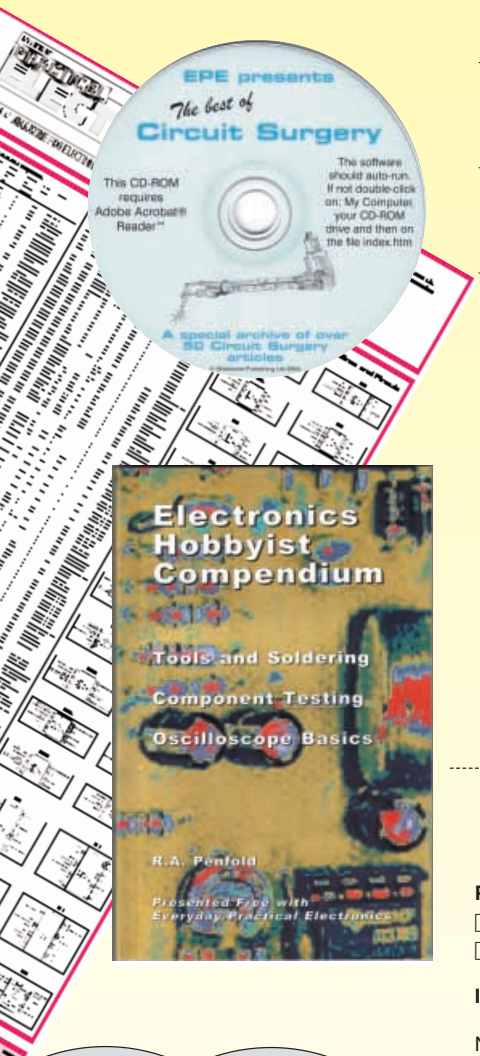
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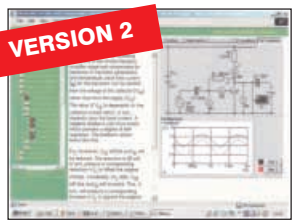


Logic Probe testing

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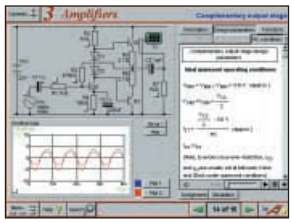
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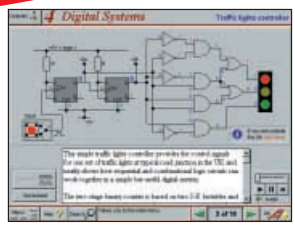


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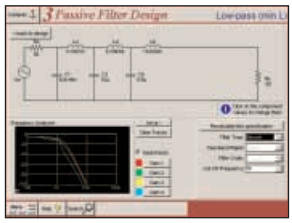
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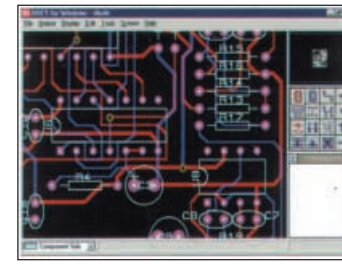
FILTERS



Filter synthesis

Filters is a complete course in designing active and passive filters that makes use of highly interactive virtual laboratories and simulations to explain how filters are designed. It is split into five chapters: **Revision** which provides underpinning knowledge required for those who need to design filters. **Filter Basics** which is a course in terminology and filter characterization, important classes of filter, filter order, filter impedance and impedance matching, and effects of different filter types. **Advanced Theory** which covers the use of filter tables, mathematics behind filter design, and an explanation of the design of active filters. **Passive Filter Design** which includes an expert system and filter synthesis tool for the design of low-pass, high-pass, band-pass, and band-stop Bessel, Butterworth and Chebyshev ladder filters. **Active Filter Design** which includes an expert system and filter synthesis tool for the design of low-pass, high-pass, band-pass, and band-stop Bessel, Butterworth and Chebyshev op.amp filters.

ELECTRONICS CAD PACK



PCB Layout

Electronics CADPACK allows users to design complex circuit schematics, to view circuit animations using a unique SPICE-based simulation tool, and to design printed circuit boards. CADPACK is made up of three separate software modules. (These are restricted versions of the full Labcenter software.) **ISIS Lite** which provides full schematic drawing features including full control of drawing appearance, automatic wire routing, and over 6,000 parts. **PROSPICE Lite** (integrated into ISIS Lite) which uses unique animation to show the operation of any circuit with mouse-operated switches, pots. etc. The animation is compiled using a full mixed mode SPICE simulator. **ARES Lite** PCB layout software allows professional quality PCBs to be designed and includes advanced features such as 16-layer boards, SMT components, and an autorouter operating on user generated Net Lists.

ROBOTICS & MECHATRONICS



Case study of the Milford Instruments Spider

Robotics and Mechatronics is designed to enable hobbyists/students with little previous experience of electronics to design and build electromechanical systems. The CD-ROM deals with all aspects of robotics from the control systems used, the transducers available, motors/actuators and the circuits to drive them. Case study material (including the NASA Mars Rover, the Milford Spider and the Furby) is used to show how practical robotic systems are designed. The result is a highly stimulating resource that will make learning, and building robotics and mechatronic systems easier. The Institutional versions have additional worksheets and multiple choice questions.

- Interactive Virtual Laboratories
- Little previous knowledge required
- Mathematics is kept to a minimum and all calculations are explained
- Clear circuit simulations

PRICES

Prices for each of the CD-ROMs above are:

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PICmicro TUTORIALS AND PROGRAMMING

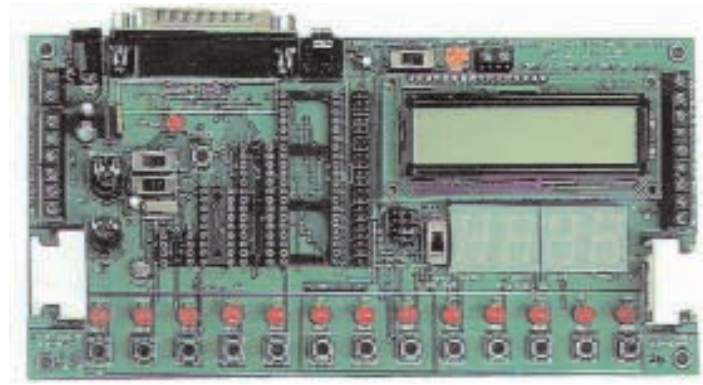
HARDWARE

VERSION 2 PICmicro MCU DEVELOPMENT BOARD

Suitable for use with the three software packages listed below.

This flexible development board allows students to learn both how to program PICmicro microcontrollers as well as program a range of 8, 18, 28 and 40-pin devices. For experienced programmers all programming software is included in the PPP utility that comes with the development board. For those who want to learn, choose one or all of the packages below to use with the Development Board.

- Makes it easier to develop PICmicro projects
- Supports low cost Flash-programmable PICmicro devices
- Fully featured integrated displays – 13 individual l.e.d.s, quad 7-segment display and alphanumeric l.c.d. display
- Supports PICmicro microcontrollers with A/D converters
- Fully protected expansion bus for project work
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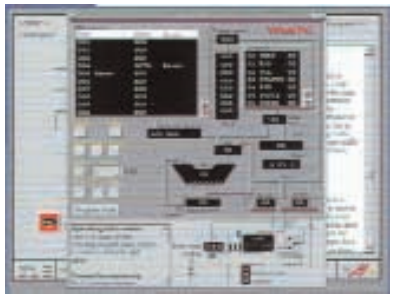
Suitable for use with the Development Board shown above.

ASSEMBLY FOR PICmicro V2

(Formerly PICtutor)

Assembly for PICmicro microcontrollers V2.0 (previously known as PICtutor) by John Becker contains a complete course in programming the PIC16F84 PICmicro microcontroller from Arizona Microchip. It starts with fundamental concepts and extends up to complex programs including watchdog timers, interrupts and sleep modes. The CD makes use of the latest simulation techniques which provide a superb tool for learning: the Virtual PICmicro micro-controller. This is a simulation tool that allows users to write and execute MPASM assembler code for the PIC16F84 microcontroller on-screen. Using this you can actually see what happens inside the PICmicro MCU as each instruction is executed which enhances understanding.

● Comprehensive instruction through 39 tutorial sections ● Includes Vlab, a Virtual PICmicro microcontroller: a fully functioning simulator ● Tests, exercises and projects covering a wide range of PICmicro MCU applications ● Includes MPLAB assembler ● Visual representation of a PICmicro showing architecture and functions ● Expert system for code entry helps first time users ● Shows data flow and fetch execute cycle and has challenges (washing machine, lift, crossroads etc.) ● Imports MPASM files.



Virtual PICmicro

'C' FOR PICmicro VERSION 2

The C for PICmicro microcontrollers CD-ROM is designed for students and professionals who need to learn how to program embedded microcontrollers in C. The CD contains a course as well as all the software tools needed to create Hex code for a wide range of PICmicro devices – including a full C compiler for a wide range of PICmicro devices.

Although the course focuses on the use of the PICmicro microcontrollers, this CD-ROM will provide a good grounding in C programming for any microcontroller.

● Complete course in C as well as C programming for PICmicro microcontrollers ● Highly interactive course ● Virtual C PICmicro improves understanding ● Includes a C compiler for a wide range of PICmicro devices ● Includes full Integrated Development Environment ● Includes MPLAB software ● Compatible with most PICmicro programmers ● Includes a compiler for all the PICmicro devices.



Minimum system requirements for these items: Pentium PC running Windows 98, NT, 2000, ME, XP; CD-ROM drive; 64MB RAM; 10MB hard disk space.

FLOWCODE FOR PICmicro

Flowcode is a very high level language programming system for PICmicro microcontrollers based on flowcharts. Flowcode allows you to design and simulate complex robotics and control systems in a matter of minutes.

Flowcode is a powerful language that uses macros to facilitate the control of complex devices like 7-segment displays, motor controllers and l.c.d. displays. The use of macros allows you to control these electronic devices without getting bogged down in understanding the programming involved.

Flowcode produces MPASM code which is compatible with virtually all PICmicro programmers. When used in conjunction with the Version 2 development board this provides a seamless solution that allows you to program chips in minutes.

● Requires no programming experience ● Allows complex PICmicro applications to be designed quickly ● Uses international standard flow chart symbols (ISO5807) ● Full on-screen simulation allows debugging and speeds up the development process ● Facilitates learning via a full suite of demonstration tutorials ● Produces ASM code for a range of 8, 18, 28 and 40-pin devices ● Institutional versions include virtual systems (burglar alarms, car parks etc.).



Burglar Alarm Simulation

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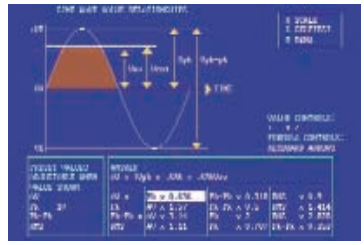
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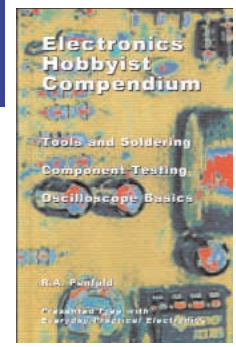
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Sine wave relationship values

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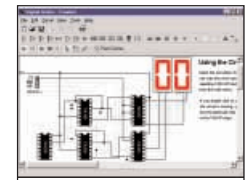
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Special Feature

Light Emitting Diodes – Operation and Applications



Anthony H. Smith, BSc. (Hons)

Part 1 – Basic principles

THE author first encountered a light emitting diode in 1971. It was about 3mm in diameter, housed in a metal can with a small, domed window on top. When biased with sufficient current, it emitted a rather feeble red light from a tiny chip just visible through the window.

At the time, he considered it something of a curiosity, as did many other students and engineers who found it interesting more for its novelty value than for its potential as a viable light source. Nowadays, however, nearly everyone is familiar with light emitting diodes, or l.e.d.s. Their use is now so widespread, it is almost impossible to avoid them. From their early uses as simple indicator lights, l.e.d.s have evolved into versatile components whose low power requirements and high efficiency make them an almost ideal light source.

Ubiquitous

They can be found in numeric displays on many consumer electronic devices and scientific instruments, they are used as backlights in mobile phones and portable computers, and recently they have moved into the territory formerly occupied by incandescent lamps and fluorescent tubes, where they are employed as a source of highly efficient illumination.

Today's range of brighter, more colourful l.e.d.s makes them well suited to a range of lighting applications where their energy-savings potential is huge. One recent estimate suggested that replacing the incandescent traffic signals in the United States with high-brightness l.e.d.s would save nearly 2.5 *billion* kWh every year!

In this series of articles, we examine the features, construction and behaviour of l.e.d.s. We look at the electrical characteristics of different l.e.d. types and examine various ways of biasing them. In particular, we contrast the merits of different l.e.d. driver circuits, and examine some of the many special-purpose l.e.d. driver i.c.s that are currently available.

The series will be concluded by looking at some of the more unusual applications for l.e.d.s, and you will discover how l.e.d.s have not just one, but *four* different uses.

Construction

Given their versatility, it is not surprising that l.e.d.s can be found in many different shapes, sizes, colours and styles. Photo 1 shows a small selection of common types. Typical products include lamps, light bar annunciators, bargraph arrays and alphanumeric devices.

Despite the enormous variety of different packages, however, nearly all l.e.d.s are based on the same physical structure responsible for generating the beam of light. The construction of a common plastic l.e.d. is shown in Fig.1.

In this typical arrangement, the semiconductor chip is attached to the cathode post, sometimes using a tiny reflector dish to maximise the light output. A short length of wire attached to the surface of the chip is bonded to the anode post. The whole assem-

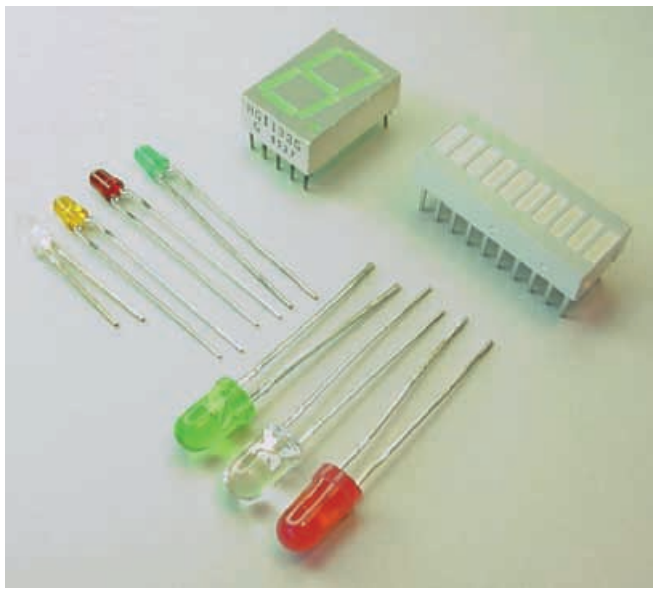


Photo 1. A small selection of common l.e.d. types

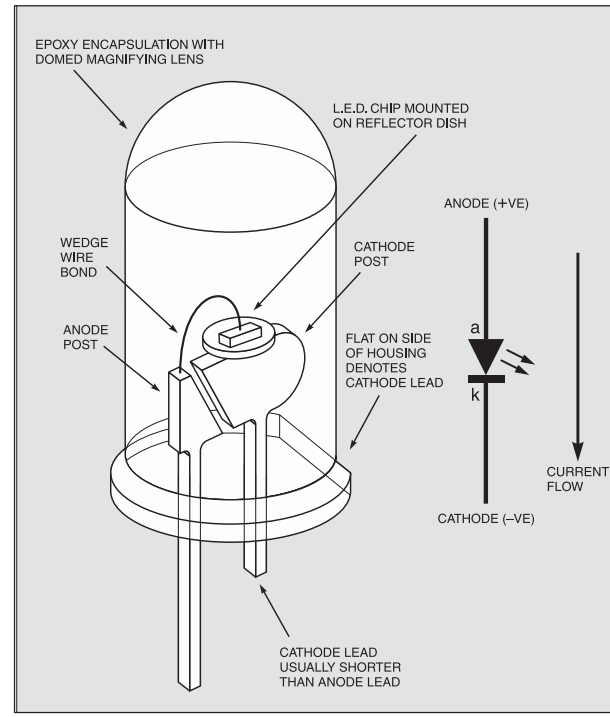


Fig.1. Construction of a typical common plastic l.e.d.

bly is housed in a moulded plastic casing, usually with a magnifying dome lens at the top. The lamp's cathode lead is usually identified by being slightly shorter than the anode lead, and there is often a flat surface on the cathode side of the moulding.

The basic structure of all l.e.d.s consists of the die, or light emitting semiconductor material, some kind of lead frame on which the die is mounted, and a plastic or epoxy encapsulation which surrounds and protects the die. L.E.D.s can be obtained in rectangular, triangular and even trapezoidal shapes. The round variety is available in several diameter sizes, the most common being the T-1 (3mm dia.) and T-1¾ (5mm dia.) sizes, although larger diameters, such as 8mm, 10mm and even 20mm, are readily available.

The electrical symbol for an l.e.d. is also depicted in Fig.1. It is largely identical to that of a standard diode, but with the addition of arrows to represent emitted light. When the anode is made positive with respect to the cathode, the l.e.d. is forward biased, and – just as in a standard diode – conventional current flows in the direction indicated.

Electricity into Light

Converting electricity into light is not a new phenomenon – the common filament bulb has being doing just that for over a century. However, the mechanism involved is significantly different to the one responsible for generating light in an l.e.d.

When current is passed through the filament of a light bulb, the electrical resistance of the filament, just as in any other conductor, results in power dissipation. The electromagnetic energy produced is given off as heat and light. Generally, the higher the temperature of the filament, the greater the total radiation emitted, and the greater the proportion of that is light. This process, known as *incandescence*, produces broadband visible radiation which is a function of the temperature of the light source.

The l.e.d., on the other hand, makes use of a phenomenon called *luminescence*, which is the name given to all forms of visible radiant energy due to causes other than temperature. There are several types of luminescence, such as *electroluminescence, chemiluminescence, photoluminescence,* and others. Luminescence refers to the narrow-band radiation emitted by a change in energy states within a material when it is excited by an external source.

In any forward-biased *pn* junction, a recombination of charge carriers – holes and electrons – takes place, mainly close to the junction itself. During this recombination process, the energy possessed by each unbound electron is transferred to another state. In all semiconductor *pn* junctions, some of this energy is given off as heat, and some in the form of *photons*, or light energy. The photons have a radiation frequency which is characteristic of the semiconductor material itself.

In materials such as silicon (Si) and germanium (Ge), most of the energy is radiated as heat, and the emitted light is negligible. However, by combining specific materials to produce compounds such as gallium arsenide phosphide (GaAsP), it is possible to maximise the light output, thereby producing an efficient light source. This process, known as *electroluminescence*, results in emitted light that is either invisible (infrared), or which lies in the visible part of the spectrum.

Unlike the filament bulb, l.e.d.s emit energy in narrow wavelength bands of the electromagnetic spectrum. The composition of the materials in the semiconductor chip determines the wavelength, and therefore the colour, of the emitted light. For example, a "blend" of aluminium gallium indium phosphide (AlGaInP) tends to produce light in the red to amber range, while l.e.d.s constructed from indium gallium nitride (InGaN) generally produce blue and green light.

A Brief History

Electroluminescence was first observed in silicon carbide (SiC) by Captain Henry Joseph Round almost a century ago in 1907. Born in Staffordshire, Round was a prolific inventor who notched up over a hundred patent applications, and worked for many years for the Marconi Company, at one time as personal assistant to Guglielmo Marconi.

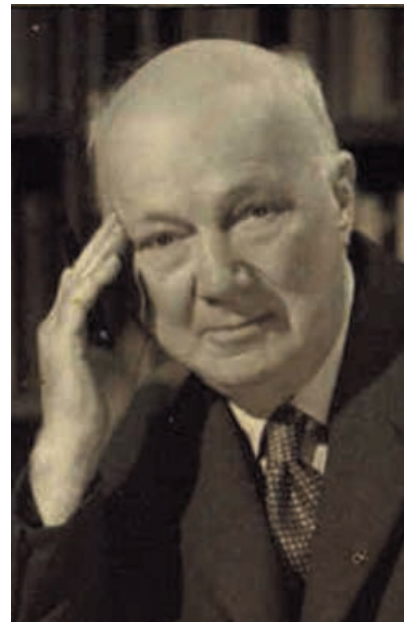


Photo 2. Captain H. J. Round. Courtesy www.captain-round.co.uk.

Much of Round's research was in the relatively new field of wireless communications, and he did considerable work on the thermionic valve, being one of the first to discover that it could generate continuous wave oscillations.

At the outbreak of the First World War, Round was seconded to Military Intelligence with the task of building a network of valve-based direction-finding stations to cover the entire Western Front. These stations, which Round had developed just prior to the onset of war, were successful in pinpointing the location of enemy transmitters.

In May 1916, in the hours before the Battle of Jutland, Captain Round's system detected a seven-mile change of position of the German fleet 300 miles away at Willhelmshaven. This was a clear indication that the German ships had put to sea, thus giving the British fleet invaluable intelligence. For his services to the country Captain Round was awarded the Military Cross.

It was in 1907, however, that Round noticed that yellow light was emitted when he passed an electrical current through a silicon carbide detector, and in a letter to *Electrical World*, he reported that "the application of an electric potential across silicon carbide could effect the generation of light."

Lossev and Destriau

Ironically, Round did not pursue his discovery, and it was not until 1923 that the effect was re-discovered by O. V. Lossev of the Nijni-Novgorod Radio Laboratory in Russia. Lossev correctly assumed that the observed effects represented the inverse of Einstein's well-known photoelectric effect, and the phenomenon is now known as the *Lossev Effect*.

The next recorded observation of electroluminescence was by Georges Destriau in 1936-37, who reported the emission of light from zinc sulphide (ZnS) powders after applying an electrical current. Destriau worked in the laboratories of Marie Curie in Paris. The Curies had been early pioneers in the field of luminescence as a result of their research into radium. Destriau is said to be the first person to have coined the word "electroluminescence" to describe the phenomenon he observed.

Clearly, the work of Round, Lossev and Destriau was of fundamental importance in the field of electroluminescence, but who exactly was the "father" of the l.e.d.? In one way or another, several individuals have been credited with this title. In 1952, for example, Heinrich Welker, a Siemens scientist, laid the scientific foundations for the development of the l.e.d. with his pioneering research into gallium arsenide.

Further developments in the early 1960s have been attributed to researchers at the RCA Laboratories in Princeton, USA, and at the Philips Research Laboratories in Aachen, Germany. At Texas Instruments, Bob Biard and Gary Pittman developed an infrared l.e.d., the TI-SNX-100, which was originally sold at the exorbitant price of $130!

Holonyak

Although these, and other, scientists have contributed to modern l.e.d. research, it is clear that one individual towers above all others in the field of semiconductor light emission. The son of Slavic immigrants who settled in southern Illinois, Nick Holonyak is generally regarded as the true heir to the throne in the kingdom of l.e.d. development.

Whilst at the University of Illinois in 1954, Holonyak was a student of John Bardeen who had just arrived from Bell Telephone Laboratories after inventing the transistor with Messrs Brattain and Shockley. Perhaps as a result of such illustrious tuition, Holonyak went on to develop a staggering range of semiconductor devices, such as tunnel diodes, transistors, *PNPN* switches and silicon-controlled rectifiers (SCRs).

If you have a dimmer switch in your house, thank Holonyak – he created the triac version of the SCR, the main component in all dimmer switches. It was in 1960, however, that Holonyak developed the first

GaAsP *PN* junction. Within two years, he had developed the visible-light semiconductor laser, and in 1962 while at General Electric (GE), he invented the first practical light-emitting diode, which was later commercialised by GE.

In recognition of his outstanding contributions to the research and practical applications of light emitting diodes and lasers, Holonyak has been showered with glittering prizes. His list of honours include the U.S. National Medal of Science, membership in the Russian Academy of Sciences and the Japan Prize, essentially Japan's Nobel Prize.

To cap it all, in 2002, he was selected as a fellow of the American Association for the Advancement of Science, having been chosen for his "pioneering contributions to the realisation of high-performance visible light emitting diodes and injection lasers".

Emission Impossible?

Despite the ground-breaking work of Holonyak and his peers, the early l.e.d.s produced very little light and critics doubted whether they would ever form a viable source of electrical light emission. However, several companies, such as chemicals giant Monsanto, saw a future market for GaAsP l.e.d.s, and after consultations with Holonyak and GE they decided to press on with l.e.d. development, and rival companies such as Hewlett Packard also entered the arena.

As a result of this vision and commitment, light emitting diodes have evolved considerably over the past four decades. The first commercial units began to appear in the late 1960s, usually consisting of a compound of gallium arsenide (GaAs). By combining the metal gallium with arsenic (a highly toxic material sometimes used as rat poison!), the world's first solid-state light source was born.

Many of the first commercially successful GaAs l.e.d.s had a spectral peak at 950nm. Being in the infrared region, they were completely invisible to the human eye. The first commercially usable visible l.e.d.s started to appear in the late 1960s, and the 1970s saw rapid growth in the l.e.d. market as improved devices were used in numeric displays for calculators and then digital watches.

During the 1970s, additional colours and wavelengths became available. The most common materials were gallium phosphide (GaP) for green and red, and gallium arsenide phosphide (GaAsP) which could be combined to produce orange, high efficiency red, and yellow.

Up to the 1970s, most l.e.d.s required an operating current of 20mA, or more, to produce adequate light output. However, in the late 1970s, new "low current" devices began to appear, typically made from gallium phosphide doped with zinc oxide. These l.e.d.s provided high brightness at low current levels of just a few milliamps, or less.

L.E.D. development continued apace in the 1980s, with new types appearing that were brighter and more efficient than those produced using older technologies. During this period, a new material, gallium aluminium arsenide (GaAlAs) was developed which provided superior performance over earlier l.e.d.s. The new types were over 10 times brighter than standard l.e.d.s due to increased efficiency and novel die structures. Additionally, the voltage required for operation was lower, thereby reducing the overall power consumption.

Despite these advances, there remained significant drawbacks with the GaAlAs material. In particular, it was only available in a red 660nm wavelength. However, in the 1990s, l.e.d.s made from a new material, indium gallium aluminium phosphide (InGaAlP) started to appear. Having a dominant wavelength that could be as low as 550nm or as high as 630nm, the new types were available in green, yellow, orange and orange-red.

Around this time, the first l.e.d.s bright enough to be used in outdoor applications began to appear. Usually made from aluminium gallium arsenide (AlGaAs), these red l.e.d.s appeared as high-mount vehicle brake lights, and were even employed in a range of traffic lights.

Birth of the Blues

During the 1990s, companies such as Siemens, Cree and Nichia were pioneering research into producing blue l.e.d.s. Some of the first blue l.e.d.s appeared in 1991, and were fabricated from the same material used to make some types of sandpaper - the super hard crystal silicon carbide (SiC). The availability of blue l.e.d.s made it possible to create full-colour advertising signs and even small video displays.

Being such a hard and brittle crystal, however, made silicon carbide a difficult material to work with, and many of the early SiC l.e.d.s were very expensive and had a relatively high failure rate. Consequently, research into other materials led to l.e.d.s made from compounds such as gallium nitride (GaN) and indium gallium nitride (InGaN).

Modern blue l.e.d.s are over 100 times more efficient than earlier types and can produce excellent brightness at relatively low current levels. Today, blue l.e.d.s can be found in traffic signals, and combined with other colours are used in huge video display boards inside sports stadiums and in full-colour scrolling advertising signs.

Attractive Features

As well as their obvious versatility, there are many other features that make l.e.d.s an attractive and extremely useful light source, particularly when compared with other light emitting mechanisms such as tungsten filament lamps and gas discharge tubes. Being made of plastics and resin, l.e.d.s have superb mechanical strength allowing them to withstand considerable vibration and shock. As there is no glass to shatter and no filament to break, l.e.d. lamps can withstand much more physical abuse than the incandescent lamp.

Since l.e.d.s do not depend on thermal radiation to produce light, they tend to be free of waste and wear and consequently have very long lifetimes. When operated properly, many l.e.d. lamps can be expected to provide over 10 years of continuous use, thereby minimising the need for costly maintenance.

It is not true that l.e.d.s generate no heat at all, and we describe shortly how some high-power types actually require heatsinking under certain conditions! In general, however, the process of converting electrical current into light is an efficient one, and generates little heat compared to incandescent lamps. Inevitably, this leads to significant energy savings.

In order to produce the same amount of light as an incandescent lamp, an l.e.d. consumes only a fraction of the electrical power. For example, an l.e.d. cluster designed to replace a 30W incandescent bulb in an automotive application would consume only around 2W while producing the same level of brightness.

Perhaps the most appealing feature of the l.e.d., though, is the ease with which it can be "driven". Since the voltage and current levels are low, the power requirements are usually much less than those of other light sources. As well as making the l.e.d. highly suitable for battery-powered, and even solar-powered, applications, it also makes it much simpler to design the drive circuits.

Later, we start to examine the techniques and circuits that can be used not just to drive an l.e.d., but also to get the best out of it in different applications. First, however, we must review a little of the terminology associated with l.e.d.s and light sources.

Terminology

When designing an l.e.d. circuit, one of the main considerations is "how bright must it be?". For visible-light l.e.d.s (i.e., not infrared applications), "brightness" is very much a subjective quantity. Furthermore, our visual sensitivity to light varies strongly as a function of wavelength. The human eye has maximum sensitivity to light in the yellow-green part of the spectrum (around 550nm), where it is around 20 times more sensitive than the red part of the spectrum (above 660nm). Thus, a red l.e.d. emitting exactly the same light energy as a green l.e.d. would appear considerably dimmer to the human eye.

You will be familiar with electrical quantities such as voltage, current, impedance, and so on. However, you may be less conversant with quantities associated with photometry, quantities such as luminance which at one time or another has had several apparently arcane units, such as the Stilb, Apostilb, Lambert, foot-Lambert, Blondel, Skot and Nit!

Fortunately, when dealing with l.e.d.s, three quantities, namely *luminous flux, luminous intensity* and *luminous efficacy*, are generally sufficient for describing the photometrical behaviour of a particular device. In simple terms, we can conceive of luminous flux as light energy radiating from a point source and crossing through a unit area on the surface of an imaginary sphere. The unit of luminous flux is the *lumen* (lm) or *millilumen* (mlm).

Naturally, the larger the amount of luminous flux crossing a given area, the greater will be the associated luminous intensity. The unit of luminous intensity is the *candela* (cd) or *millicandela* (mcd). The luminous intensity of an l.e.d. is the figure which most closely represents its "brightness".

In an ideal l.e.d. all of the electrical energy entering the device would be converted into emitted light. In practical devices, however, the conversion process is not 100% efficient, so it is important to have some measure of the emitted light energy relative to the input power. This is specified

Table 1: Electrical Characteristics @ 25°C for HLMP-1000 and HLMP-1503

Symbol	Characteristic	Colour	Min.	Typ.	Max.	Units	Test Conditions
I_V	Luminous Intensity	Red	0·5	1·0		mcd	I_F = 20mA
		Green	1·0	5·0			I_F = 10mA
θ	Viewing Angle	Red		60		Deg.	
		Green		60			
V_F	Forward Voltage	Red	1·4	1·6	2·0	V	I_F = 20mA
		Green	1·5	2·1	2·7		I_F = 10mA
η_V	Luminous Efficacy	Red		–		lm/W	
		Green		595			
τ_S	Speed of Response	Red		10		ns	
		Green		500			

in terms of luminous efficacy, which has units of lumens per watt (lm/W).

The efficacy of a given l.e.d. depends on several factors, in particular the kind of chip material, and also on the wavelength of the emitted light.

Typical Characteristics

In order to get a feel for the terms used when specifying an l.e.d., we will examine the characteristics of two Agilent (formerly Hewlett Packard) l.e.d.s, the green HLMP-1503, and the older red HLMP-1000. Table 1 lists some of the most important characteristics specified at given levels of *forward current*.

The forward current, symbol I_F, is simply the current flowing through the l.e.d. when it is forward biased. Not surprisingly, the forward current has a pronounced effect on the luminous intensity: the greater the current, the brighter the l.e.d. The HLMP-1000 and HLMP-1503 both exhibit a fairly linear relationship between intensity and current. For example, doubling the forward current will roughly double the intensity, although this is not the case for all l.e.d.s.

We can see that the green l.e.d. is typically five times brighter than the red type, even though the green l.e.d.'s specified forward current is half that of the red part. Whether or not a luminous intensity of 1·0mcd to 5·0mcd is sufficient will naturally depend on the particular application. Although it may be adequate for dull ambient light conditions, it may be necessary to drive the l.e.d. at a higher forward current, or select a brighter part, if it is to be viewed in bright sunlight.

The viewing angle is the off-axis angle at which the luminous intensity has fallen to half its axial value. This is the reason why l.e.d.s appear brighter when viewed "full on". The HLMP-1000 and HLMP-1503 both have a reasonably broad viewing angle (60 degrees). Some l.e.d.s have a much "narrower" viewing angle. This is often the case for "high intensity" or "superbright" types, where the light is focused into a relatively narrow beam in order to maximise the light intensity.

The speed of response denotes the rate at which an l.e.d. can be switched on and off. For many applications, this characteristic is unimportant. However, for high speed signaling applications such as fibre optic telecommunications, the l.e.d.'s switching speed can be a critical factor.

One of the l.e.d.'s most important electrical characteristics is its *forward voltage*, denoted V_F. When biased at moderate current levels, the voltage drop across a common signal diode such as the 1N4148 will be in the region 600mV to 700mV. The forward voltage of an l.e.d., though, tends to be much greater than that of a signal diode, and is influenced considerably by the colour. In this example, the red l.e.d. has a lower forward voltage than the green part, even though it is operating at twice the forward current.

It is not uncommon for blue and white l.e.d.s to exhibit forward voltages in the region 3V to 5V. As we will see shortly, the relationship between V_F and I_F can play an important role in designing a suitable driver circuit.

Maximum Ratings

Like all electrical components, l.e.d.s have *absolute maximum ratings* which should be observed when designing a particular drive circuit. Exceeding the maximum ratings may result in degraded light output, a shortened life time, or possibly complete failure of the l.e.d.

The *maximum d.c. current* rating specifies the upper limit on the d.c. forward current. The green HLMP-1503 has a maximum current rating of 30mA, whereas the red HLMP-1000 can tolerate a maximum level of 50mA.

The *peak operating forward current* indicates the maximum transient current that can be tolerated for brief durations. This is usually specified at a given frequency and duty cycle, and provides a measure of the maximum pulsed current that the part can tolerate. The HLMP-1503, for example, can tolerate peak currents as large as 90mA.

Another area where the l.e.d. differs from the "standard" diode is in terms of the *maximum reverse voltage*, V_R. Whereas rectifier diodes like the 1N4005 can tolerate reverse voltages as high as 600V, most l.e.d.s have maximum reverse breakdown voltages as low as 5V. When the breakdown voltage is exceeded, the l.e.d. experiences an "avalanche" breakdown. The reverse current flow increases rapidly as higher reverse voltages are applied. Unless steps are taken to limit the reverse current, exceeding the maximum V_R rating could damage the device.

Other ratings such as *maximum operating temperature* and *maximum power dissipation* must be taken into account. Also, remember that l.e.d.s are semiconductor devices which can be damaged by excessive electrostatic discharge (ESD).

The Bright Stuff

The HLMP-1000 and HLMP-1503, having a luminous intensity of 1·0mcd to 5·0mcd, are not exceptionally bright by today's standards. When used as general purpose indicators on products such as video equipment, personal computers, photocopiers, test equipment, and so on, l.e.d.s with intensity of around 5mcd to 20mcd are usually adequate. However, more demanding applications – particularly where there is high ambient brightness such as outdoor uses – call for brighter l.e.d.s.

During the 1980s, manufacturers experimented with novel compounds, and found that adding aluminium and phosphorus to the conventional gallium arsenide material to produce gallium aluminium arsenide phosphide (GaAlAsP) resulted in much greater intensity.

In the 1990s, developments in the compound indium gallium aluminium phosphide (InGaAlP) led to "ultrabright" l.e.d.s in red, orange, yellow and green, which produced high brightness at modest forward current levels of around 5mA to 20mA.

Terms such as "high intensity", "superbright", "hyperbright", "ultrabright", and even "super ultrabright", are often used to describe l.e.d.s in the high brightness category. The precise meaning of these terms often varies from one manufacturer to another. As a rough guide, the high intensity types usually provide intensity in the 10mcd to 70mcd range, whereas the intensity of the superbright, hyperbright and ultrabright types may be anywhere from 20mcd to 200mcd.

At the top end of the range come the super ultrabright types (sometimes called "very high intensity" or "high power") which often have intensity in the 100mcd to 1000mcd range, and may even be as high as 40 candelas or more!

High brightness l.e.d.s are quickly replacing conventional lighting in a wide variety of applications, such as stop lights, pedestrian signals and road hazard signs. Being easily visible in daylight makes them ideally suited to use in variable message signs such as the one in Times Square, New York, which displays commodities, news and other information. Recent technical breakthroughs have made high brightness l.e.d.s available in the entire colour spectrum, including red, yellow, green, blue, violet and white.

Light Source

Companies such as Agilent, Nichia, Siemens and Toshiba produce very bright l.e.d.s in a range of colours. Some of the brightest l.e.d.s currently available are made by a company called Lumileds Lighting of San Jose, California. Photo 3 shows a selection of Lumileds l.e.d.s from the "Luxeon" range of power light sources. Of particular interest is the Luxeon "Star" at the bottom right.

This device comprises a powerful l.e.d. mounted on an aluminium-core p.c.b. which allows the device to be mounted on a heatsink for optimum cooling. It is available in white, green, blue, royal blue, cyan, red, red-orange and amber. The standard version of the Luxeon Star can be operated at a forward current as high as 350mA. Note that this is a continuous d.c. current rating, not a peak rating, and is much greater than the maximum forward current rating of the majority of common l.e.d.s.



Photo 3. A selection of "Luxeon" l.e.d.s from Lumiled.

At 350mA, the luminous intensity of the Luxeon Star ranges from 80 to an incredible 825 *candelas* (not millicandelas), depending on the colour! When operated at 350mA, the forward voltage of the device is typically around 3·5V, corresponding to an electrical input power of 1·2W. Although much of this power is converted to light, a good deal is given off as heat, hence the need for heatsinking to cool the l.e.d. chip.

So bright are the Lumileds l.e.d.s that certain blue types require a Class 2 Laser safety warning, which cautions users not to stare directly into the beam!

Photo 4 illustrates a Lumileds LXHL-PE01 cyan l.e.d. connected in series with a "conventional" high brightness green l.e.d. with a forward current of 20mA flowing through them. Although the conventional l.e.d. produces good brightness, the Lumileds part is dazzling in comparison.

When testing the LXHL-PE01, the author was surprised at just how much light the sample emitted with only a few hundred microamps of forward current. With the current increased to around 50mA, the intensity was staggering.

More information on the Luxeon range of l.e.d.s can be found at **www.lumileds.com**. They can be purchased from Future Electronics (**www.futureelectronics.com**) and Farnell (**www.farnell.com**).



Photo 4. A Lumiled LXHL-PE01 cyan l.e.d. (top) in series with a "conventional" high brightness green l.e.d.

The White Stuff

We showed earlier that an l.e.d.'s emitted wavelength, and hence its colour, falls within a fairly *narrow* band determined primarily by the semiconductor compound. Therefore, given that white light contains all the colours of the visible spectrum, how is it possible to make an l.e.d. that emits white light?

Essentially, there are two techniques that may be employed to produce an l.e.d. that has a white appearance. One method consists of red, green, and blue l.e.d. chips packaged closely together, such that the emitted light beams "mix together" to form a composite colour. This kind of array is capable of producing a variety of colours, but with the appropriate currents flowing in each chip, the combination appears white.

The second technique, pioneered mainly by Nichia in Japan in the mid-1990s, employs a blue l.e.d. chip coated with a white inorganic phosphor material. When the blue light strikes the inner surface of the phosphor, the device emits a broadband white glow. In simple terms, this technique can be considered a combination of electroluminescence and phosphorescence, and is widely used in modern white l.e.d.s.

Over the past few years, white l.e.d.s have become much more commonplace and are finding applications in portable devices such as laptop computers and mobile phones, where they are well suited to backlighting the display, and are also used to illuminate the phone's keypad. High brightness types are also replacing incandescent bulbs in flashlights where their energy efficiency and ruggedness are obvious advantages.

However, like the blue l.e.d.s on which they are based, white l.e.d.s exhibit a fairly large forward voltage, sometimes as high as 5V. Naturally, this poses problems for low-voltage applications, such as battery-powered equipment with just one or two cells. However, we shall show in a later article how special circuit techniques can be used to drive white l.e.d.s from power sources as low as one volt. For the moment, though, we will examine some of the basic techniques for illuminating, or "driving", an l.e.d.

Current Control

The l.e.d. is essentially a current-controlled device in that the forward current, I_F, must be controlled, or regulated, in some way so as to produce a well-defined light intensity. We showed earlier that luminous intensity is directly dependent on the forward current, and many l.e.d.s exhibit a fairly linear relationship between the two quantities.

Forward voltage, V_F, is also dependent on forward current, although in a highly non-linear fashion. The curves shown in Fig.2, generated from actual measurements on samples of the HLMP-1000 3mm red l.e.d. and a 5mm green l.e.d., illustrate the non-linear relationship between V_F and I_F. The test data were obtained using the simple circuit shown alongside the graph, where a variable current source is used to excite the l.e.d. sample.

Note the marked difference in the shape of the characteristics. As the forward current (plotted on the Y-axis) is increased from zero, the forward voltage of the red l.e.d. also increases until it reaches around 1·6V. At this point, further increases in I_F have little effect on V_F, which remains fairly constant over the vertical part of the characteristic. The green l.e.d., however, exhibits a more gradual increase in V_F, resulting in an "exponential" shape to its characteristic.

As well as having differently-shaped characteristics, the l.e.d.s also exhibit significant differences in V_F at any given value of I_F. For example, at I_F = 20mA, the red l.e.d. has V_F = 1·65V, whereas the forward voltage of the green sample, 3·27V, is roughly twice as large.

It is often the case that l.e.d.s with shorter wavelength (blue, green, etc.) have significantly larger V_F than long-wavelength l.e.d.s (orange and red).

Resistor Biasing

The simplest way to control the l.e.d.'s forward current is to use a series resistor as

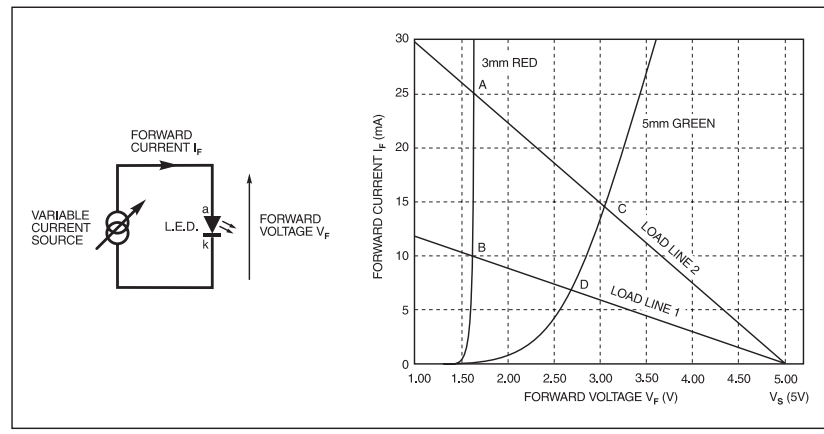


Fig.2. Operating characteristics for different l.e.d. samples.

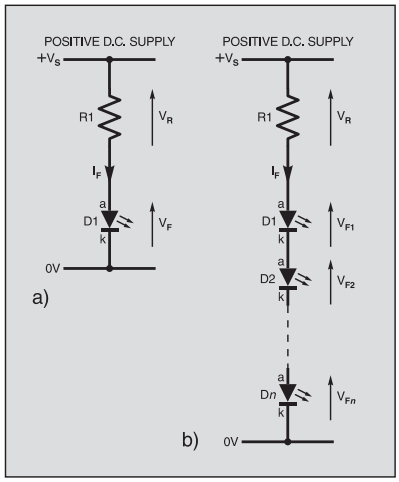


Fig.3. Using a series resistor to set forward current.

shown in Fig.3a. Since the resistor, R1, and the l.e.d., D1, are connected in series, the same current, I_F, flows through both. The magnitude of the current is given by :

$$I_F = \frac{V_R}{R1} = \frac{V_S - V_F}{R1} \qquad (A)$$

where V_R is the voltage dropped across R1, V_F is the l.e.d.'s forward voltage, and V_S is the d.c. supply voltage. This equation can be rearranged to give an expression for R1:

$$R1 = \frac{V_S - V_F}{I_F} \qquad (\Omega)$$

Therefore, assuming we have a fairly well regulated supply voltage, and knowing the desired value of forward current, we may use this formula to select R1. However, there is a problem – what value of V_F should we use?

One solution is to use the typical value quoted in the manufacturer's data sheet. However, as we saw in Table 1, V_F is usually quoted only at one value of I_F; for other values of forward current, V_F could be significantly different. Fortunately, many manufacturers also publish the l.e.d.'s characteristics, usually in a form similar to the curves in Fig.2.

Although such characteristics only represent *typical* performance, they can be useful in determining an approximate relationship between V_F and I_F.

As an example, assume we wish to operate the 3mm red l.e.d. at a forward current of 10mA from a 5V supply. The characteristic shows that V_F is approximately 1·63V at I_F = 10mA. Inserting these values into the formula gives R1 = 337Ω, the nearest preferred value being 330Ω. Using this value would establish the operating conditions at point *B* on the characteristic – see Fig.2.

If we draw a line between this point and the 5V point on the X-axis, we obtain the *load line* for a value of R1 = 330Ω.

Constructing a load line is useful in determining the operating conditions for other l.e.d. types. For instance, we see that Load Line 1 cuts the 5mm green l.e.d. characteristic at point *D*. This means that with V_S = 5V and R1 = 330Ω, the green l.e.d. would have a forward voltage of around 2·65V and a corresponding forward current of approximately 6·7mA – quite different to the red l.e.d.'s operating conditions.

The second load line, Load Line 2, corresponds to a value of R1 = 130Ω. Clearly, the difference in the operating conditions for the red and the green l.e.d. has widened. Whereas the red l.e.d.'s forward current would be 25mA, the value of I_F for the green part would be much lower, at around 14·5mA.

These examples show that the series resistance must be chosen carefully to suit a particular l.e.d. type, otherwise significant differences in forward current, leading to noticeable shifts in intensity, will arise.

Series L.E.D.s

The arrangement in Fig.3b shows how several l.e.d.s may be connected in series, provided, of course, that the supply voltage is large enough to support them. For a given value of I_F, the required series resistance is given by:

$$R1 = \frac{V_S - (V_{F1} + V_{F2} + ... + V_{Fn})}{I_F} \qquad (\Omega)$$

where *n* is the number of l.e.d.s in the string. Since the same forward current flows through each l.e.d., this approach is only suitable to l.e.d.s having similar characteristics, otherwise the luminous intensity could vary considerably from one l.e.d. to another.

Provided the l.e.d.s are of the same type, we may assume that they have the same forward voltage, V_F, and thereby simplify the expression for R1:

$$R1 = \frac{V_S - nV_F}{I_F} \qquad (\Omega)$$

Parallel L.E.D.s

For cases where the available voltage is too low to support several l.e.d.s in series, the natural alternative is to connect them in parallel. Fig.4 shows the wrong way and the right way to do this.

In Fig.4a, two l.e.d.s connected in parallel share the same series resistor, R1. However, the total current I_T flowing through R1 will not divide equally between the l.e.d.s unless they share exactly the same characteristic. For example, if we connected the above-mentioned 3mm red and 5mm green l.e.d.s in parallel, the red l.e.d., which has much lower forward voltage at all current levels, would "pull down" the common forward voltage, V_F, to its own level, thereby starving the green l.e.d. of current.

Under these conditions, I_{F1} would not equal I_{F2}, and most of the available current, I_T, would flow in the red l.e.d. As a result, the green l.e.d. would either appear very dim, or may even be completely "off". The recommended solution is shown in Fig.4b, where each l.e.d. has its own series resistor.

This approach allows each resistor to be chosen individually to produce the required intensity in its series l.e.d.

Although using a series resistor to set an l.e.d.'s forward current is a cheap and simple option, it can have significant drawbacks. In particular, fluctuations in supply voltage, V_S, and variations in V_F (caused by part-to-part differences or temperature changes) will inevitably lead to changes in I_F and luminous intensity. However, we will see in a later article how the use of a *current source* circuit can alleviate most of these problems.

Using an A.C. Supply

For cases where a suitable d.c. supply is not available, it is possible to drive an l.e.d. directly from an a.c. power source. The circuit in Fig.5a illustrates the simplest way of doing this. However, this basic solution should only be used when the peak value of the a.c. supply voltage, V_{AC}, is less than 5V, or so, otherwise the l.e.d. could suffer reverse breakdown on negative half cycles of V_{AC}.

For cases where V_{AC} exceeds 5V, one of the circuits in Fig.5b or Fig.5c may be used. The circuit in Fig.5b uses a series diode, D1, to block reverse current flow through the l.e.d. when the potential at test point TP2 is positive with respect to TP1. However, when TP1 is positive with respect to TP2, both D1 and the l.e.d. are forward biased, and the instantaneous value of forward current through the series chain is:

$$I_F = \frac{V_R}{R1} = \frac{V_{AC} - V_D - V_F}{R1} \qquad (A)$$

where V_D is the instantaneous voltage across D1 and V_F is the instantaneous forward voltage across D2.

The value of R1 must be large enough to ensure that the peak forward current (occurring when V_{AC} is at its positive peak) is less than the l.e.d.'s maximum peak forward current rating. Also, diode D1's peak reverse voltage rating must be greater than the peak negative a.c. voltage.

For low voltage applications, a signal diode such as the 1N4148 may be adequate, but for mains operation, a diode such as the 1N4004 with a reverse voltage rating greater than 350V would be necessary.

The circuit shown in Fig.5c employs D1 as a shunt across the l.e.d. to limit, or clamp, the reverse l.e.d. voltage to the "diode drop" of D1. On positive half cycles, when the l.e.d. is forward biased, the diode sees a

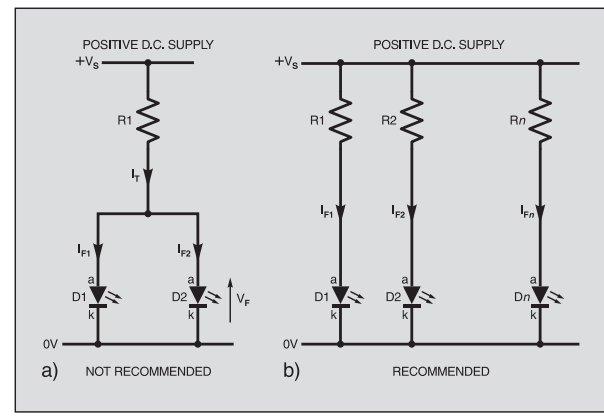


Fig.4. Connecting l.e.d.s in parallel, (a) not recommended, (b) recommended.

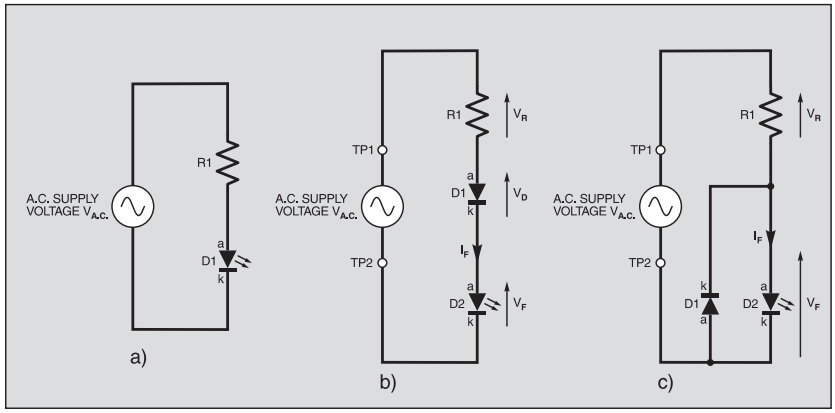


Fig.5. Operating l.e.d.s on an a.c. supply.

reverse voltage equal to the relatively small forward voltage of the l.e.d. Therefore, D1 needs only a small reverse voltage rating, allowing practically any diode with adequate current rating to be used.

Furthermore, since the diode is no longer in series with the l.e.d., no voltage is "wasted" across it, which can be a significant advantage for low voltage supplies.

The circuit in Fig.5c appears superior to that in Fig.5b, but we must also consider the power dissipation in resistor R1 which can be significant if V_{AC} is large, such as a mains-powered application. In Fig.5b, current flows through the resistor only on positive half cycles of V_{AC}, so its average power dissipation is roughly half that of the resistor in Fig.5c where current flows in R1 on *both* half cycles of V_{AC}.

Half Wave Rectification

For each circuit, the l.e.d. current, I_F, only flows on positive half cycles of V_{AC}. In other words, the l.e.d. current is *half wave rectified*, since the l.e.d. is acting not just as a light emitter, but also as a rectifying element. This fact must be taken into account when selecting the value of resistor R1 to give adequate l.e.d. brightness.

Since an l.e.d.'s apparent brightness is determined by the average forward current flowing through it, we must select a value of R1 that will set the average value of I_F sufficient to provide adequate intensity. For cases where the supply is sinusoidal, it can be shown that the value of R1 is related to the required average current, $I_{F(av)}$, by the equation:

$$R1 = \frac{(\sqrt{2} \times V_{RMS}) - V_F}{\pi \times I_{F(av)}} \qquad (\Omega)$$

where V_{RMS} is the root-mean-square (r.m.s.) value of the a.c. voltage source.

For example, let's say we wish to establish an average current of 20mA through the 3mm red l.e.d. using the circuit of Fig.5c with a 6V r.m.s. voltage source. Taking V_F = 1·65V, the equation yields R1 = 108·8Ω, the nearest preferred value being 110Ω.

For a half wave rectified sinewave, the peak and average current values are related by $I_{F(pk)} = \pi \times I_{F(av)}$, so in this example, the peak current value is $\pi \times$ 20mA = 62·8mA, safely within the HLMP-1000 l.e.d.'s peak rating.

Mains Operation

Operating an l.e.d. directly from the mains voltage supply can be extremely dangerous and should not be attempted unless proper precautions are taken. The lack of an isolating transformer means that the l.e.d. could be at live mains potential. Unless steps are taken to insulate the l.e.d. in some way, this could prove fatal.

A further problem involves the power rating of the series resistor. When operating on a 240V r.m.s. mains supply, the resistor required to set an average l.e.d. current of just 20mA would need a power rating in excess of 10 watts!

However, assuming that the l.e.d. can be properly insulated to prevent lethal shocks, the circuit shown in Fig.6 provides an alternative approach for mains operation.

Here, most of the mains voltage is dropped across capacitor C1, which – being a reactance – dissipates no power. The small-valued resistor R1 is necessary only to limit power-up transients and requires only a low power rating. For a particular value of average forward current, $I_{F(av)}$, the required value of C1 is given by:

$$C1 = \frac{I_{F(av)}}{0{\cdot}9 \times \pi \times V_{RMS} \times f} \qquad (F)$$

where f is the frequency of the mains supply and V_{RMS} is the r.m.s. value of V_{AC}. This equation takes account of the fact that the capacitor current, I_C, flows on both half cycles of V_{AC}, whereas I_F flows in the l.e.d. only on positive half cycles.

For example, with V_{RMS} = 240V, and a 50Hz supply frequency, an average current of $I_{F(av)}$ = 10mA would require a 295nF capacitor. Choosing a 330nF preferred value would result in $I_{F(av)}$ = 11·2mA.

Although this technique requires a class X capacitor rated at full mains voltage and safety requirements, the capacitor size would be much smaller than a high power resistor. Furthermore, since C1 dissipates no power, the heat generated by the circuit is negligible.

Next Month

Having shown how l.e.d.s can be operated on sinusoidal a.c. sources, we shall show in the next part of this series how other a.c. waveshapes, such as square waves, can be put to good use in varying an l.e.d.'s brightness. We will also look at the best ways to interface l.e.d.s with logic devices, and examine a variety of l.e.d. flasher circuits.

Acknowledgement

The author would like to thank Mark van den Berg, Lumileds' European Marketing Manager, for his assistance with this article.

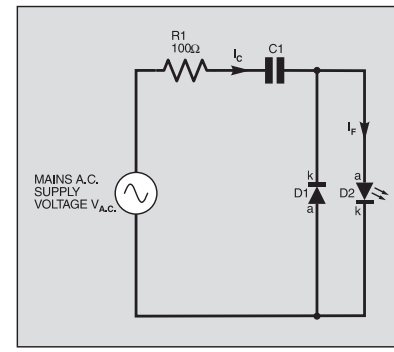


Fig.6. Mains powered l.e.d. circuit. Note the safety requirements given in the text for this circuit.

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High Speed Binary To Decimal For PICs



Peter Hemsley

It really is amazingly fast!

MANY microcontroller projects use alphanumeric liquid crystal displays (l.c.d.s) to display information to the user. This information includes numeric data which would normally be in binary format. However, most people like to see numbers as decimal, thus making binary to decimal an essential library routine for the programmer.

In this maths lesson we show you how to express a binary number in terms of powers of ten, and so create a super-fast 16-bit binary-to-decimal routine for PICs.

Converting base 2 to base 10 directly would prove excessively long because there would be 16 bits to process, each of them individually, therefore a different method is required. No doubt you are all familiar with writing binary numbers as hexadecimal digits, converting hex to decimal would involve processing only four hex digits, which is a significant simplification.

Base Line

If the four hex digits of a 16-bit binary number are represented by H3 (msd), H2, H1 and H0 (lsd) then a number N can be expressed as:

$$N = H3 \times 4096 + H2 \times 256 + H1 \times 16 + H0$$

Expand the expression to:

$$N = H3 \times 4000 + H3 \times 90 + H3 \times 6 + H2 \times 200 + H2 \times 50 + H2 \times 6 + H1 \times 10 + H1 \times 6 + H0$$

Now group together the terms of powers of ten:

$$N = H3 \times 4 \times 1000 + H2 \times 2 \times 100 + (H3 \times 9 + H2 \times 5 + H1) \times 10 + 6 \times (H3 + H2 + H1) + H0$$

Writing each term separately:

$$D0 = 6 \times (H3 + H2 + H1) + H0 \quad (\times 1)$$
$$D1 = H3 \times 9 + H2 \times 5 + H1 \quad (\times 10)$$
$$D2 = H2 \times 2 \quad (\times 100)$$
$$D3 = H3 \times 4 \quad (\times 1000)$$

The Dxs are not decimal digits (as yet) but they are expressed in terms of powers of ten and the sum total of them does add up to the original binary number N. We want to use a single byte for each Dx but D0 could exceed 255, also D1 contains a multiply by 9 and 5, both being inconvenient to write in assembler. So let's try and simplify the multiplications to overcome these problems, starting with the original expression:

$$N = H3 \times 4096 + H2 \times 256 + H1 \times 16 + H0$$

We can re-write this as $N = H3 \times (4100 - 4) + H2 \times (260 - 4) + H1 \times (20 - 4) + H0$

This looks better, no odd numbers, some easy multiplication by powers of two, and four zeros (which means they can be ignored, $X \times 0 = 0$). On the downside there are three subtractions, but as we shall see these will eventually combine into a single term.

Now repeat to obtain the Dxs:

$$N = H3 \times 4 \times 1000 + H3 \times 100 - H3 \times 4 + H2 \times 2 \times 100 + H2 \times 6 \times 10 - H2 \times 4 + H1 \times 2 \times 10 - H1 \times 4 + H0$$

Grouping the powers of ten:

$$N = H3 \times 4 \times 1000 + (H3 + H2 \times 2) \times 100 + (H2 \times 6 + H1 \times 2) \times 10 + H0 - (H3 + H2 + H1) \times 4$$

$$D0 = H0 - (H3 + H2 + H1) \times 4 \quad (\times 1)$$
$$D1 = H2 \times 6 + H1 \times 2 \quad (\times 10)$$
$$D2 = H3 + H2 \times 2 \quad (\times 100)$$
$$D3 = H3 \times 4 \quad (\times 1000)$$

Everything looks good so far except for D0, which could have a positive or a negative value. First let's find the limits of D0 by putting numbers into the expression. Since each hex digit ranges from 0 to 15 the minimum and maximum values for D0 are:

$$D0 = 0 - (15 + 15 + 15) \times 4 = -180$$
$$D0 = 15 - (0 + 0 + 0) \times 4 = 15$$

Therefore the value of D0 can range from –180 to +15.

This would not be very convenient to write assembler code for, we need the values either all positive or all negative. Making the values all negative will have advantages as we shall see later.

Standardised Signs

To make D0 negative for all values, we can subtract any number greater than 15. The number should be a multiple of 10 so as not to change the least significant decimal digit of the value, If we subtract 20 this will make all values of D0 negative and then we can simply add 2 to the next higher order of power of ten, i.e. D1, to keep the net result the same. So:

$$D0 = H0 - (H3 + H2 + H1) \times 4 - 20$$
$$D1 = H2 \times 6 + H1 \times 2 + 2$$

Now find the limits and the subtraction required for D1, D2 and D3:

$$D0 = H0 - (H3 + H2 + H1) \times 4 - 20$$
$$D1 = H2 \times 6 + H1 \times 2 + 2 - 130 = H2 \times 6 + H1 \times 2 - 128$$
$$D2 = H3 + H2 \times 2 + 13 - 60 = H3 + H2 \times 2 - 47$$
$$D3 = H3 \times 4 + 6 - 70 = H3 \times 4 - 64$$

Ok, we now have an expression for each of the decimal digits, but each Dx also contains values of higher order powers of ten. What we must now do is divide each Dx by 10 and add the result of the division to next higher order Dx, the remainder of the division being our much desired decimal digit.

This is where making the Dx's negative pays dividends. To do the division we simply keep adding 10 until the result goes positive and at the same time subtracting 1 from the next higher order Dx. This results in a positive remainder in the Dx. An overflow is needed for D3. This is D4 (ten thousands digit) with an initial

Listing 1

```
; Fast 16-Bit Binary to Decimal by Peter Hemsley
; Input: 16-bit binary in NUMHI and NUMLO
; Output: Decimal (BCD) digits in D4(msd), D3, D2, D1, D0(lsd)
; No temporary variables required
; Code size: 46 instructions
; Execution time: Variable, approx. 150 to 170 cycles
Bin2DecFast
        movf    NUMHI,w     ; Hex Digit 0X00 (H2)
        iorlw   0xF0        ; w  = H2 – 16
        movwf   D0          ; D0 = H2 – 16
        movwf   D1          ; D1 = H2 – 16
        addwf   D1,f        ; D1 = H2 * 2 – 32
        addwf   D1,f        ; D1 = H2 * 3 – 48, C = 1
        movwf   D2          ; D2 = H2 – 16
        rlf     D2,f        ; D2 = H2 * 2 – 31
        swapf   NUMHI,w     ; Hex Digit X000 (H3)
        iorlw   0xF0        ; w  = H3 – 16
        addwf   D2,f        ; D2 = H3 + H2 * 2-47 Done!
        movwf   D3          ; D3 = H3 – 16
        addwf   D3,f        ; D3 = H3 * 2 – 32
        addlw   D'52'       ; w  = H3 + 36
        addwf   D0,f        ; D0 = H3 + H2 + 20
        swapf   NUMLO,w     ; Hex Digit 00X0 (H1)
        iorlw   0xF0        ; w  = H1 – 16
        addwf   D1,f        ; D1 = H2 * 3 + H1 – 64
        addwf   D0,f        ; D0 = H3 + H2 + H1 + 4, C = 1
        rlf     D0,f        ; D0 = (H3 + H2 + H1) * 2 + 9,
                              C = 0
        comf    D0,f        ; D0 = -(H3 + H2 + H1) * 2 – 10
        rlf     D0,f        ; D0 = -(H3 + H2 + H1) * 4 – 20
        movf    NUMLO,w     ; Hex Digit 000X (H0)
        andlw   0x0F        ; w  = H0
        addwf   D0,f        ; D0 = H0 – (H3 + H2 + H1) * 4
                              – 20 Done!
        rlf     D1,f        ; C  = 0, D1 = H2 * 6 + H1 * 2 –
                              128 Done!
        movlw   D'7'
        movwf   D4          ; D4 = 7
        addlw   D'3'        ; w  = 10, C = 0
        rlf     D3,f        ; D3 = H3 * 4 – 64 Done!
mod0
        addwf   D0,f        ; D(X)   = D(X) mod 10
        decf    D1,f        ; D(X + 1) = D(X+1) + D(X) div
                              10
        skpc
        goto    mod0
mod1
        addwf   D1,f
        decf    D2,f
        skpc
        goto    mod1
mod2
        addwf   D2,f
        decf    D3,f
        skpc
        goto    mod2
mod3
        addwf   D3,f
        decf    D4,f
        skpc
        goto    mod3
        return
```

value of 0 plus 7 carried over from D3. The final set of expressions are:

D0 = H0 – (H3 + H2 + H1) × 4 – 20
D1 = H2 × 6 + H1 × 2 – 128
D2 = H3 + H2 × 2 – 47
D3 = H3 × 4 – 64
D4 = 7

Reduce D0 to D3 such that D(x) = D(x) mod 10, and D(x + 1) = D(x + 1) + D(x) div 10

PIC Routine

The PIC routine in Listing 1 is the author's implementation of these expressions to produce a 16-bit binary-to-decimal routine. It has been highly optimised to use the PIC's architecture and instructions to the full, resulting in a compact and very fast routine. If you require the digits to be in ASCII text format, simply add 48 to each digit before outputting it.

For the interest of budding PIC programmers, and experts alike, here is some of the PIC-trickery (programming tricks) used by the author to make the routine more efficient.

Multiplying a number by 2 is usually achieved using RLF with the Carry clear. However, if the Carry is set prior the execution of RLF then: RLF X = X × 2 + 1.

To make a positive number negative, the sequence COMF and INCF would normally be used. But what, in mathematical terms, would be the result of COMF alone? Simply it is COMF X = – X – 1. To obtain the lower nibble of a number in the W register ANDLW 0x0F would be used, and followed by ADDLW 0xF0 (–16 decimal) to subtract 16 from the W register. These two instructions can be replaced by a single IORLW 0xF0.

If the Carry is required to be clear (or set) for a particular operation try and find a place in your program where the Carry is guaranteed to be in the required state. This saves having to use CLRC and SETC instructions, the author uses these instructions only when necessary.

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Lising 1 is available for *Free* download from our Downloads site, access via **www.epemag.wimborne.co.uk**. It is in the *PIC Tricks* folder within the main PIC source codes folder. □

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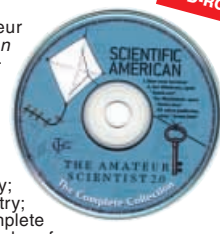
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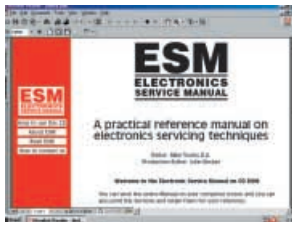
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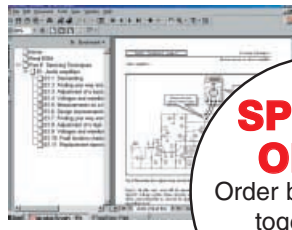
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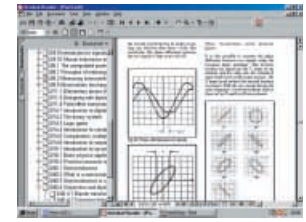




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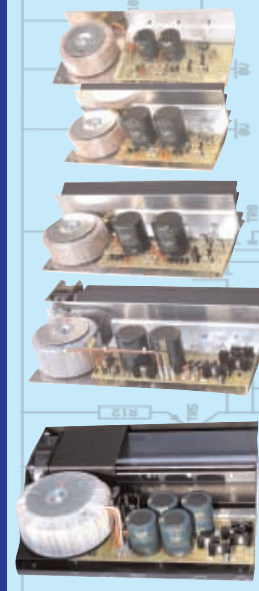
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